INCORPORATING ITS INTO CORRIDOR PLANNING: SEATTLE CASE STUDY - FINAL REPORT

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FINAL REPORT

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Incorporating ITS into Corridor Planning: Seattle Case Study

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Support from

**Parsons Brinckerhoff Quade and Douglas
and CH2M Hill**

FINAL REPORT

Incorporating ITS into Corridor Planning:

Seattle Case Study

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Abstract

As Intelligent Transportation Systems (ITS) technologies mature and become ready for deployment through use of regular funding sources, ITS will need to become fully integrated into the established transportation planning process. This process involves choices among competing projects within financial and other constraints. ITS components will in many cases be combined with more conventional transportation components as part of an alternative to address a specific transportation problem. This raises many questions about how to select and evaluate ITS projects as an integral element of traditional transportation construction projects. In addition, transportation planners often have less experience with ITS than with other types of transportation improvements, and hence analytical techniques that adequately address the ITS component have not been developed.

To address these issues the ITS Joint Program Office (JPO) of the United States Department of Transportation (USDOT) tasked Mitretek Systems to investigate the incorporation of ITS into the transportation planning process. To accomplish this task Mitretek initiated a multi-year, two-phase study effort. The goal of the study was to develop a methodology for public sector investment analysis. The methodology needed to be able to analyze ITS investments and to produce case-study based estimates of the relative benefits of ITS infrastructure investments versus conventional transportation investments. A goal objective of the study was to identify areas where improved methods or tools are needed for this type of analysis.

This report documents an analysis methodology, the Process for Regional Understanding and EValuation of Integrated ITS Networks (PRUEVIIN), that meets these goals. It also provides results from the application of this methodology. The study was done using the structure of a Major Investment Study (MIS) of transportation alternatives for the area north of Seattle, Washington.

KEYWORDS: ITS, simulation model, regional planning model, major investment study, alternatives analysis, corridor planning study, Benefit/Cost analysis, ITS costs, PRUEVIIN.

Foreword

This is the final report on the Seattle Case Study. It includes and replaces the earlier drafts that provided a discussion of major study elements: namely, drafts dated May 1997, June 1997, and March 1998. The main differences between this final report and the March 1998 draft are: this report includes results from the analysis of all five alternatives; a revised executive summary, abstract and acknowledgement; new section 7.9 Cost of Alternatives; and revised section 8.0 Validation. Other new sections include section 9.0 Summary of Results and section 10.0 Lessons Learned. Appendix B, Detail Alternative Cost Worksheets, has also been added.

Acknowledgments

Mitretek Systems would like to acknowledge the following persons and organizations for their guidance and support in the conduct of this study.

Paula Ewen and Mac Lister of HVH, our task managers at the Federal Highway Administration (FHWA) ITS Joint Program Office (JPO).

The internal US Department of Transportation (USDOT) advisory team of Doug Laird, Brian Gardner, and Sam Zimmerman of HEP, John Gerner of HTV, and Ron Fisher and Charlie Goodman of the Federal Transit Administration (FTA). This group provided input on the overall task scope and reviewed project progress and final results.

Karen Richter, Robert Sicko, Nick Roach, Larry Blain and their staff at the Puget Sound Regional Council (PSRC), Pete Briglia of Washington State DOT (WsDOT), and all other members of the Seattle Advisory Panel. This panel was formed early in the task to provide advice on the definition of the alternatives to be studied and to assess the applicability of the final methodologies for use by state and local governments. A complete list of organizations and contacts is provided in Appendix A of the report.

Parsons Brinckerhoff Quade & Douglas (PBQD) and CH2M Hill, our sub-contractor team in the Seattle area. Specifically, we would like to acknowledge Chris Wellander, Cathy Strombom, Youssef Dehghani, Murli Adury, Tim Bevan and Stephanie MacLachlan. This team provided the initial transportation networks for all of the alternatives; developed and executed the cost methodology; provided local coordination with transportation agencies, state and local governments; and provided significant inputs to, and review of, the drafts and the final report.

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Introduction

The goals of this study were to develop a methodology for incorporating Intelligent Transportation Systems (ITS) into the transportation planning process and apply the methodology to esitmate ITS costs and benefits for one case study. A major result from the study included the development of an analysis method for quantitatively assessing ITS impacts, called the Process for Regional Understanding and EValuation of Integrated ITS Networks (PRUEVIIN). Other significant results include the assessment of benefits from an integrated set of ITS services at the regional and corridor level, and lessons learned about incorporating ITS into the planning process. The following sections set the context for and provide a summary discussion of these findings.

Key Study Accomplishments

1. <u>Developed an analysis methodology (PRUEVIIN)</u>. PRUEVIIN evaluates the unique aspects of ITS strategies (impacts/benefits/costs) along with more traditional corridor improvements. Traditional corridor alternatives have in the past focused on capacity and other improvements designed to relieve expected or recurrent congested conditions. The techniques have focused on average travel and conditions. However, many of transportation problems, delays, and congestion that occur in the real world are the result of non-recurrent incidents or operational inefficiencies. Traditional corridor study methods and measures of effectiveness tend to be insensitive to solutions such as ITS strategies designed to address problems arising from these non-recurrent and operational issues. ITS strategies focus primarily on improving operations and the transportation system's response to changing conditions, improving reliability of the system and letting travelers know the true condition of the transportation system.
   A goal of the study was to develop a set of integrated methods that incorporate in the analysis the types of problems and solutions that ITS strategies are attempting to remedy. This includes the system's response to varying non-recurrent conditions and the impact of information. Another important aspect of this same goal was to implement the process in an integrated framework that can analyze the net effect of the traditional and ITS elements in an overall solution to the corridor's transportation needs. This is especially important since the impacts of each element (ITS and traditional) in an overall corridor solution may interact, producing results that are not simply the sum of the individual element improvements. The PRUEVIIN methodology accomplishes this goal.

   For the study an existing commercial planning model (EMME/2) and simulation model (INTEGRATION) were used. The INTEGRATION model supports analysis of trips from each origin to each destination (similar to the regional models) but can also trace how vehicles actually move through the network. The ability to trace individual vehicles is a key feature for incorporating mode choice, route guidance, and other ITS strategies into the analysis. Key elements of the methodology are the capture of both ITS and traditional transportation improvements in both of these models; the interplay of the models to assess corridor improvements in the context of a regional network; and the development of a series of scenarios (representative travel days) to capture the conditions and effects of non-recurring congestion.

In this study the PRUEVIIN methodology was applied for an analysis year of 2020 (a typical 20 year planning time-frame), but the methodology can also be used for any time horizon, as well as for the conduct of near term "what-if" analyses by operational personnel. Since the inception of the study, PRUEVIIN has been used to support the Metropolitan Model Deployment Initiative (MMDI) evaluation program. A study in the Seattle area using the same sub-area was conducted for a horizon year of 1997-98 (*ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results*, Mitretek Systems, June 1999).

2. <u>Produced Measures of Effectiveness (MOE's) for comparing alternatives.</u> These measures reflect typical MIS issues and also capture the impacts of ITS strategies. A key phase in any MIS is the development of the MOE's that are used to evaluate the alternatives under study and reflect the issues/concerns of those in the community making the decision. Typically, measures of transportation service, costs, mobility and system performance, financial burden, and environmental/community impacts are considered. These measures, however, are usually only calculated based upon the average weekday or expected conditions. Variation in conditions (e.g. travel demand, weather, accidents) and the transportation system's response to them is not part of the analysis and consequently does not enter into the decision process. Incorporating variation in conditions is key to showing the benefits of ITS and other strategies focused on improving the operation of the system. In the study several new MOE's were analyzed that are more representative of the impacts of ITS. These new measures include reduction in travel time variability, probability of a severely delayed trip, vehicle-km traveled at various speed ranges, and number of stops per vehicle-km traveled.

3. <u>Developed representative-day scenarios.</u> A methodology was developed to determine the number and characteristics of the representative-day scenarios necessary to capture the variation in conditions and the effects of non-recurrent congestion. Previous studies have shown that ITS strategies can have significant impact on anomalous traffic conditions that, even though they are relatively rare, can contribute a disproportionate amount of delay and other costs. To assess the alternatives in this study that include ITS strategies, the analysis had to incorporate these anomalous traffic conditions. Since the network simulation model is capable of representing time-varying conditions, the AM peak travel conditions are characterized into a reasonable sample of scenarios that are both typical and anomalous of conditions in the study area.

Each scenario represents a combination of conditions common to the study area that may lead to the traveler experiencing very different conditions and possibly a different travel choice. The characterization of the sub-area conditions and the scenarios was obviously constrained by available data. These considerations focused attention on the following characteristics: traffic/trip volumes and their space-time patterns; weather conditions; and the effect of accidents and other incidents on traffic conditions. For the Seattle study it was determined that 30 scenarios were required to capture the yearly range of day-to-day variations in travel conditions. The probability of occurrence of each scenario during the year was also determined. For each of the 6 alternatives, the full set of scenarios was run. The resultant MOE's were then multiplied by the probability of the occurrence of the scenario. This produces an annualized value for each MOE. This annualized roll-up allows the even-playing-field examination of ITS elements alongside traditional capacity improvements.

4. <u>Developed techniques to measure and calibrate the simulation model.</u> This calibration approach accounted for the within-day and the day-to-day travel time variations in the transportation system. This is important because if system variability is overstated, then ITS-related benefits associated with adaptive control or ATIS will likely be overstated. Likewise, if system variability is understated, then the benefits of ITS technologies will likely be understated. The techniques developed include the use of an 18-month archive of travel time estimates along the I-5 freeway in Seattle, collected at 15-minute intervals between 6:00 AM and 9:30 PM.

Observations on Methodology Development and Application

1. It is possible using a reasonable amount of resources to integrate regional travel forecasting and sub-area simulation analyses to capture the impacts of ITS and other operational strategies. The Case Study has successfully interfaced the two model systems for this purpose.

2. Simulation tools require additional levels of detail and representative coding than are typically found in regional models. If accurate simulations are to be developed then extra time must be spent in network checking and detailing to ensure that all models represent the physical features of the system at the same level of precision. Likewise, executing the integrated system (regional model + sub-area simulation + feedback) will also require additional effort, especially when representative day scenarios are used for the estimation of ITS benefits.

3. There are increased needs for data collection to support the simulation tools beyond the data collection associated with the support of travel demand models. Additional information beyond what is carried in the regional model systems will need to be obtained, geocoded, and entered into the model system. This includes data on signal operational plans, time variation in demand, and the information on weather, incidents, construction, etc. used to construct the representative day scenarios.

4. The characteristics and size limits the regional model and simulation model platforms used in the study were a significant factor in the design of the methodology. Understanding these characteristics is crucial for properly transferring data between the two platforms. One specific issue is the use of very short “dummy” links, a common practice in planning models. However, these short links are incompatible with the high-volume freeway coding requirements of the simulation model. Therefore, in applying the methodology used in this study one needs to be aware that each pairing of modeling systems will have its own set of issues that will have to be examined.

5. There are also inherent differences in operation and performance between regional and simulation tools. Each represents travel and the behavior of individuals differently. For example, regional models, especially in horizon year forecasts, often have assigned volumes on links or across screenlines which exceed coded capacity (the actual physical capacity of the facility). On the other hand, simulation models by their design cannot assign volumes to links beyond their capacity. Since these two models define capacity differently, special care must be taken. In the horizon year analyses, one should therefore always check for this over saturation condition prior to attempting a simulation run. The trips assigned over saturation can either be deferred to outside the assignment period or diverted around the sub-area. In the study a deferred trip measure of effectiveness was defined to show the level of oversaturation when it did occur. The explicit treatment of queuing in simulation and not in the regional system presents similar issues. These differences in impedance calculation led to the conclusion to only feedback the relative changes between alternatives from the simulation to the regional model. If absolute values from the simulation are fed directly back into the regional model a discontinuity between links within the simulation area and those without is created.

6. Validation is a crucial step in developing an integrated model system. The regional model system parameters and coding should be examined and modified to reflect the new services under study. For example, if ramp meters are to be examined in the analysis it is important to represent the bottlenecks in capacity due to traffic merging for all unmetered intersections in the network. This is achieved by assigning a merge bottleneck penalty to all intersections, and then for the ramp-metered intersections, the merge bottleneck on the main lanes downstream of the ramp is removed. This is a very different approach from simply increasing the capacity on the links downstream of the ramp to above the mid-link flow levels.

Background

As ITS capabilities become ready for deployment through use of regular funding sources, they will need to be integrated into the established transportation planning process. This process involves choices among competing projects within financial and other constraints. ITS components will in many cases be combined with more conventional transportation components as part of an alternative to address a specific transportation problem. This raises many questions about how to select and evaluate ITS projects as an integral element of traditional transportation construction projects.

In addition, transportation planners often have less experience with ITS compared to other types of transportation improvements, and hence analytical techniques that adequately address the ITS component have not been developed. In light of this, any approach to study these issues has to include:

- Reviewing existing procedures and developing a quantitative investment analysis methodology for state/local use in transportation planning.
- Developing case study-based estimates of relative costs and benefits of ITS versus conventional investments.
- Identifying where improved methods of project

To address these issues the ITS Joint Program Office (JPO) of the United States Department of Transportation (USDOT) tasked Mitretek Systems to investigate the incorporation of ITS into the transportation planning process. A review of current state-of-the-practice revealed that consideration of ITS is typically not an integral part of transportation planning. Rather, ITS is considered an operational detail worked out after infrastructure planning. In many cases ITS was considered too difficult to evaluate with respect to transportation planning and then relegated to operational analysis because of a lack of evaluation tools. In response to the JPO tasking, Mitretek initiated a multi-year, two phase study effort. The goal of the study was to develop a methodology for public sector investment analysis. The methodology needed to be able to analyze ITS investments and to produce case-study based estimates of the relative benefits of ITS infrastructure investments versus conventional transportation investments. A secondary goal of the study was to identify areas where improved methods or tools are needed for this type of analysis.

This study was conducted in two phases with the overall objective of both phases being to identify how best to incorporate ITS into the transportation planning process. The phase 1 analysis involved a look at the current process of prioritization of projects addressing many different transportation problems and needs across a region, such as those reflected in the Transportation Improvement Program (TIP) approval process. These results have previously been published (*Incorporating ITS into Planning: Phase 1 Final Report*, USDOT, FHWA-JPO, Washington, DC, September 1997).

The phase 2 analysis focused on the development and evaluation of alternative solutions to a given transportation problem that, depending upon evaluation results, could then be incorporated into the Transportation Plan and eventually the TIP. An example of this type of analysis is the approach taken when conducting a Major Investment Study (MIS). Although this second type of analysis is the focus of this report, methodologies utilizing cost and benefit information have been developed that are of value in both types of analyses. Phase 2 of the study started in July 1996 and selected the Seattle area to develop specific methodologies for the evaluation of project alternatives in the context of a MIS. The results of this phase are the focus of this report.

Case Study Approach

Rather than relying on a hypothetical transportation network and problem statement, Mitretek took the approach of conducting a case study. Specifically, we selected a sub-region or corridor in the Seattle area that would be suitable for analysis, i.e., where alternate solutions to a particular transportation problem can be developed, and where a variety of ITS strategies are applicable. For illustration, if the problem to be addressed is effects from congestion along an urban corridor, the list of alternative solutions might include “do-nothing”, construct a new road, add lanes to existing routes, provide HOV lanes, provide ramp metering, provide incident management systems, add bus or light rail service, as well as combinations of these listed capabilities. In this study ITS services were analyzed both separately and in combination with conventional construction options.

The alternative solutions were examined in detail, in close coordination with a local transportation consulting firm with which Mitretek contracted to support the study (specifically, the team of Parsons Brinckerhoff Quade Douglas and CH2MHill). The study team developed an analysis methodology to adapt and extend conventional transportation improvement modeling and impact analyses. The resulting methodology is designed to be more sensitive to the impacts of the selected ITS strategies and to provide for comparability across the evaluated alternatives. The analysis methodology developed and its results were reviewed with planning staff in the region at various points in the study to assess appropriateness and usefulness.

Scope

For the purposes of this study, it was assumed that a MIS type effort was needed as part of the normal transportation planning process to assess specific alternatives to solve a specific transportation problem in the Seattle area. The geographic scope of the study is a large corridor or sub-area of the transportation network. This geographic context, which parallels that called out in MIS guidance, allows for a variety of transportation alternatives to be considered and evaluated, without being so broad as to dilute the evaluation process with an intractable number of potential alternatives.

The range of transportation improvement projects considered in the study included construction of new roads or lane miles, conventional signal installations, transit improvements, Transportation Demand Management measures, Advanced Traveler Information Systems, Advanced Traffic Management Systems, and Advanced Public Transportation Systems. The study scope did not include Automated Highway Systems or Commercial Vehicle Operations.

The scope of the study does include the identification of a study area, the definition of alternatives to be considered, the development of specific analysis approaches, and the results from applying these analysis approaches. In our case we chose to evaluate several traditional transportation build alternatives in the corridor, with and without ITS components. Simulation modeling and other analytical techniques were applied to these selected cases to quantify benefits and assess the alternatives against a common set of measures of effectiveness (MOE's).

To support the decisions that must be made within the planning process, a wide variety of analytical techniques are used to provide estimates of the potential transportation impacts and costs of alternative investment strategies. Analysis techniques differ in level of detail and effort required to use them at different stages in the planning process (translating to the amount of resources required). While all of these techniques are important and are often used in combination in a conducting a planning study, this study focuses on the analysis requirements of a corridor level planning study and makes extensive use of both planning and simulation models.

Since this is a federally sponsored study providing guidance for transportation planners in metropolitan regions, the specific alternatives assessed are not tied to "actual" Seattle decisions. The study has a wider scope than the actual Seattle situation and considered alternatives beyond those that might be supported in the Seattle environment.

Study Corridor Description

The Seattle I-5 North Corridor was selected for the case study. (See Figure ES-1) The North Corridor contains the two primary continuous north-south routes into the Seattle Central Business District (CBD), I-5 and State Route (SR) 99. The dominant traffic flow direction is associated with commuting to and from the Seattle CBD and the areas immediately south. However, these two routes also carry the significant contra-flow traffic to Boeing-Everett and other points north of the Seattle CBD. These routes provide the only high capacity access of the six routes crossing the Ship Canal, the waterway that bisects Seattle west of Lake Washington. The I-5 North Corridor becomes a bottleneck to mobility for Seattle's topographically constrained regional travel. Significant highway capacity increases through construction are unlikely in the densely developed areas extending north from the CBD and across the Ship Canal. The diversity of modes and facility types in the study corridor promotes the idea of using ITS operational approaches.

In keeping with an MIS approach, a general problem statement is formulated to guide the identification of alternatives, including ITS, and the measures of effectiveness for the case study. The problem statement for the I-5 North Corridor is **"**Develop and evaluate alternatives to reduce congestion and improve mobility along the North Corridor extending from the Seattle CBD north to SR 526."

In all, six alternatives including a baseline were analyzed for the target year of 2020. (See Figure ES-2) The ITS Rich alternative contains significant improvements in advanced traveler information services (ATIS), advanced traffic management systems (ATMS) surveillance and signal coordination enhancements, transit priority, and incident management. Two traditional construction alternatives were also defined: major improvements to a single-occupancy vehicle (SOV) expressway and a set of high-occupancy vehicle (HOV) plus busway improvements. These were analyzed alone and in combination with the same package of ITS Rich improvements. For each alternative a

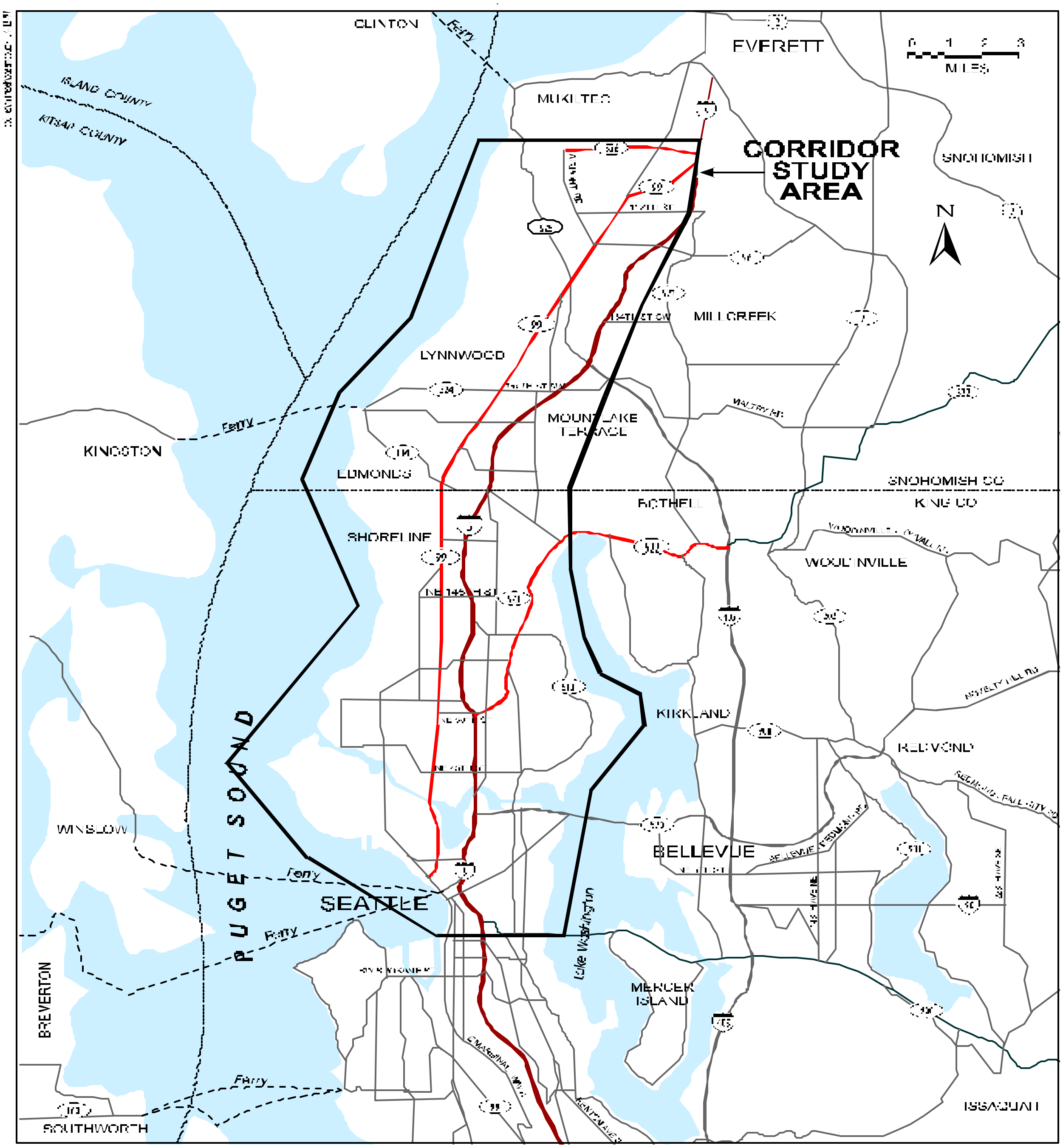


Figure ES-1. Detailed Analysis Area for the North Corridor

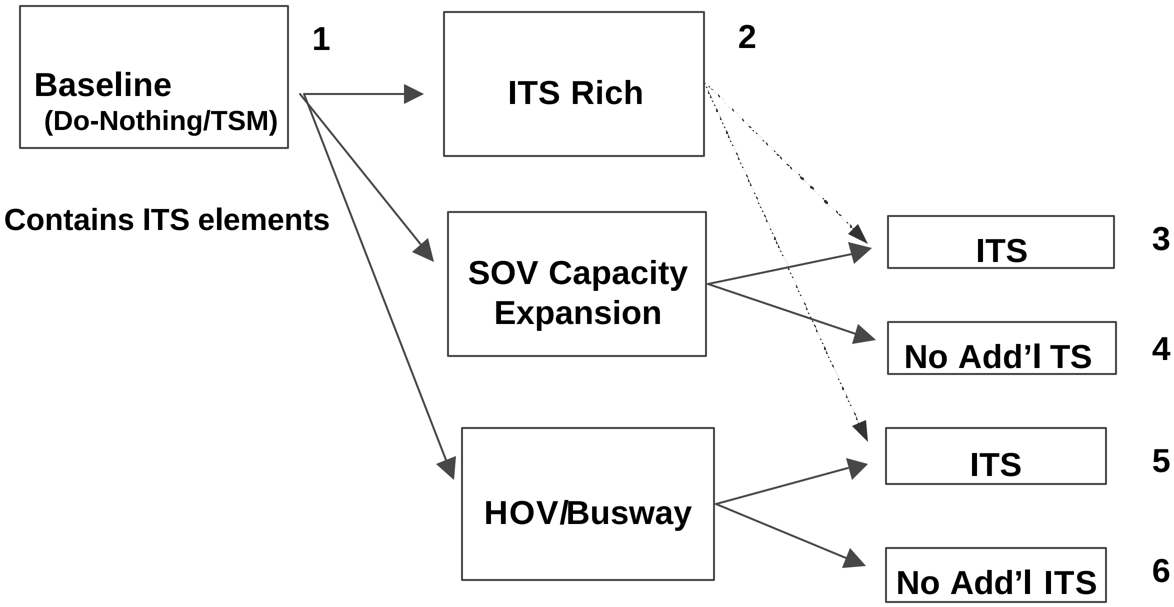


Figure ES-2. Description of Alternatives

number of measures of effectiveness were calculated. All alternatives were compared to a Baseline (Do-Nothing/TSM). The dotted line leading from the ITS Rich alternative indicates that the other ITS enhancements are derived from it, but each has been tailored to complement the specific build option.

Overview of PRUEVIIN

The Process for Regional Understanding and EValuation of Integrated ITS Networks (PRUEVIIN*)* was developed and applied as part of this study. PRUEVIIN is a two-level hierarchical modeling system for assessing the impacts of ITS at the regional and corridor scale. (See Figure ES-3) At the higher (regional) level, the analysis of overall travel patterns and the system's response to average/expected conditions is analyzed using a traditional regional planning model. Output from this analysis is then fed into a more detailed sub-area simulation model capable of modeling time-varying conditions and demands, as well as individual vehicle-level capabilities and routing decisions. At this level, the detailed traffic operations, queuing, and buildup/dispersion of demand are captured, as well as the real-time response of travelers to information. Feedback is then carried out to ensure that the impacts to expected conditions, estimated in the sub-area model, are reflected in the regional analysis. In theory, one could model the entire region using only a simulation model, but this is not yet practical for desktop PCs and current software. The EMME/2 planning model (macro scale) was used for the regional planning model, and INTEGRATION 1.5 (meso scale) for the detailed simulation model. One of

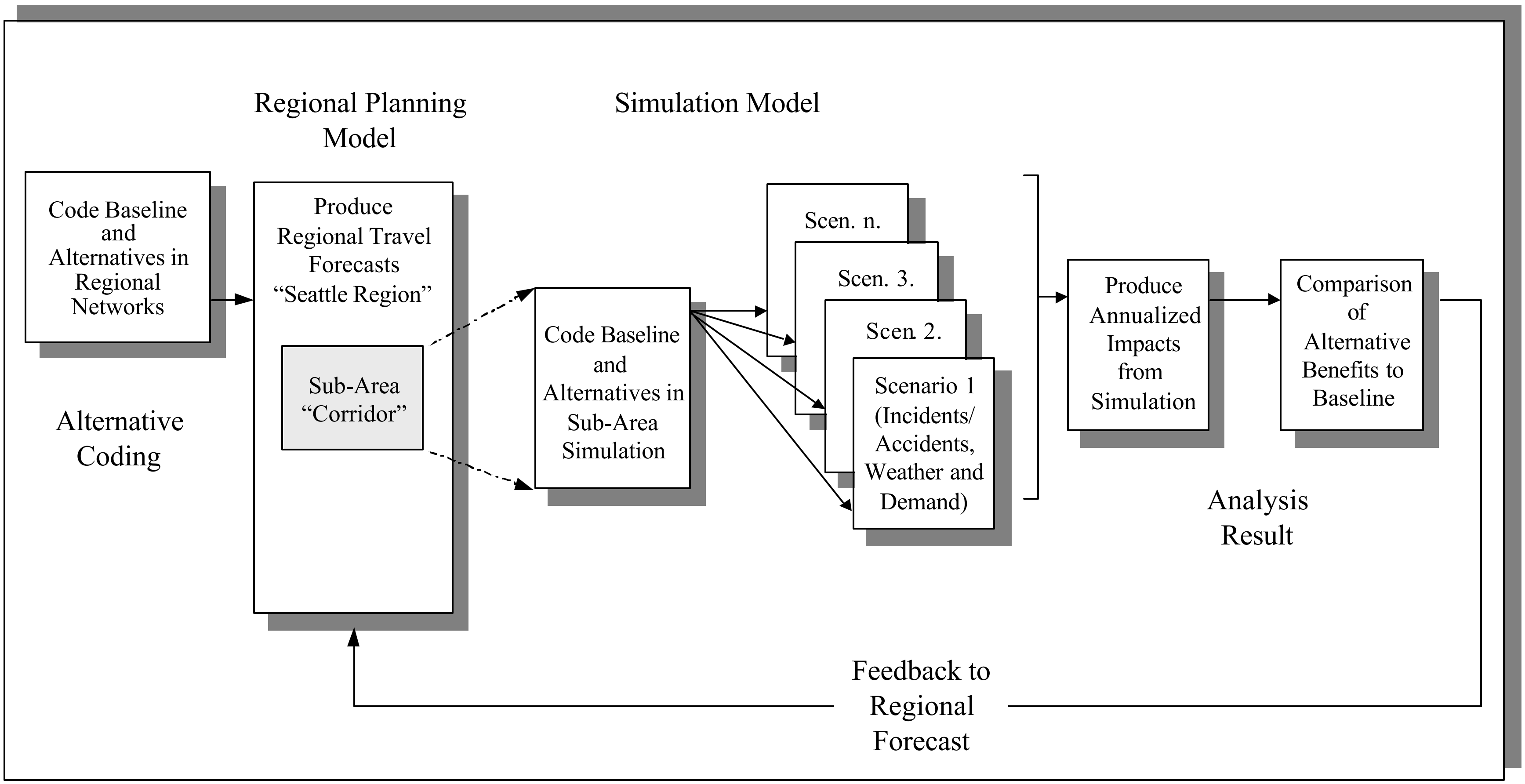


Figure ES-3. Analysis Methodology Overview

the challenges in the study was to develop expertise in mapping both the inputs and analysis results between the two modeling levels. The modeling system contains several pre- and post-processors that manage the interfaces between the models and generate results from model output data. A unique approach is taken to account for the variability in the transportation system. The weather, travel demand, and accident/incident rate variation are analyzed for the corridor over a period of time. A set of representative-day scenarios is developed that, when appropriately weighted, can be used to represent an entire year. This step requires a trade-off between adequately capturing the variability in these multiple parameters and still keeping the number of scenarios to a manageable level.

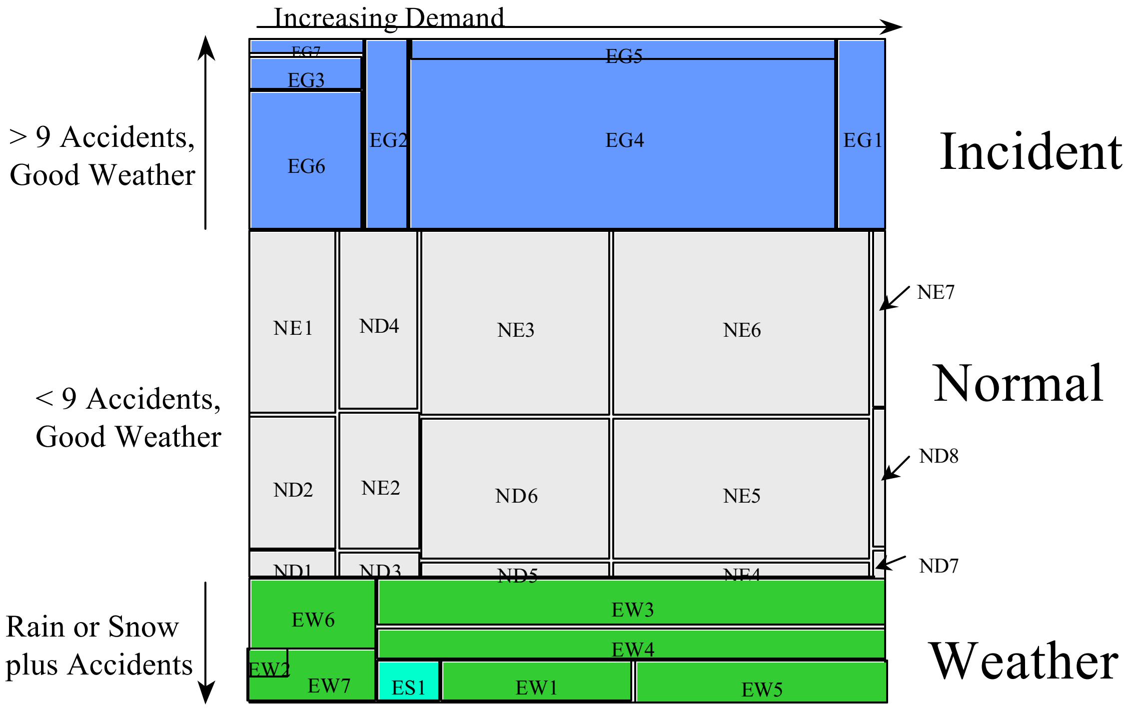
The analysis process starts by building both the planning and simulation networks. In this study the approved Puget Sound Regional Council (PSRC) 1990 travel demand modeling process was used. The simulation model for the corridor/sub-area is generated from this base network. A validation process was then conducted to validate that both models were representative of the 1990 time period. Next each alternative is defined and coded in both models for the horizon year, in this case 2020. Each alternative is first run in the planning model and the appropriate performance measures generated. From this run a demand table is generated for input to the simulation model. The simulation model is then run for each alternative with this demand and the representative-day scenarios. The appropriate performance measures are generated for each scenario and then annualized across all scenarios. Adjustments (feedback) between the two models are then made to ensure that the benefits generated in the corridor are properly reflected in the region.

Key Alternative Analysis Results

In order to understand the presentation of the results from the alternatives analysis, a further explanation of the concept of representative-day scenarios and the specific measures of effectiveness used in this study is required. Although these two concepts were initially presented in the discussion of key accomplishments, the next two sections provide a broader description, along with a few examples.

Representative-Day Scenario Example

To account for the system variability, two years of travel demand, weather, and accident/incident data in the corridor were analyzed. Using cluster analysis and other statistical techniques, 30 separate representative-day scenarios were developed to reflect these conditions. Figures ES-4 and –5 depict these scenarios. Note that each scenario constitutes a combination of weather, accidents/incidents and travel demand. The size of the box represents the frequency of occurrence of the scenario during the year. For example, using the two figures in combination indicates that scenario NE3 is a non-event (no major incident), normal weather, and normal demand scenario. Scenario EG1 contains a major incident, under good weather with demand 10% greater than average. The scenarios are arranged in such a manner that those with extreme conditions are at the edges of the figure (i.e. top, bottom and right-hand edge).


Increasing Demand
> 9 Accidents, Good Weather
< 9 Accidents, Good Weather
Rain or Snow plus Accidents
EG7
EG3
EG6
EG2
EG5
EG4
EG1
Incident
NE1
ND4
NE3
NE6
NE7
Normal
ND2
NE2
ND6
NE5
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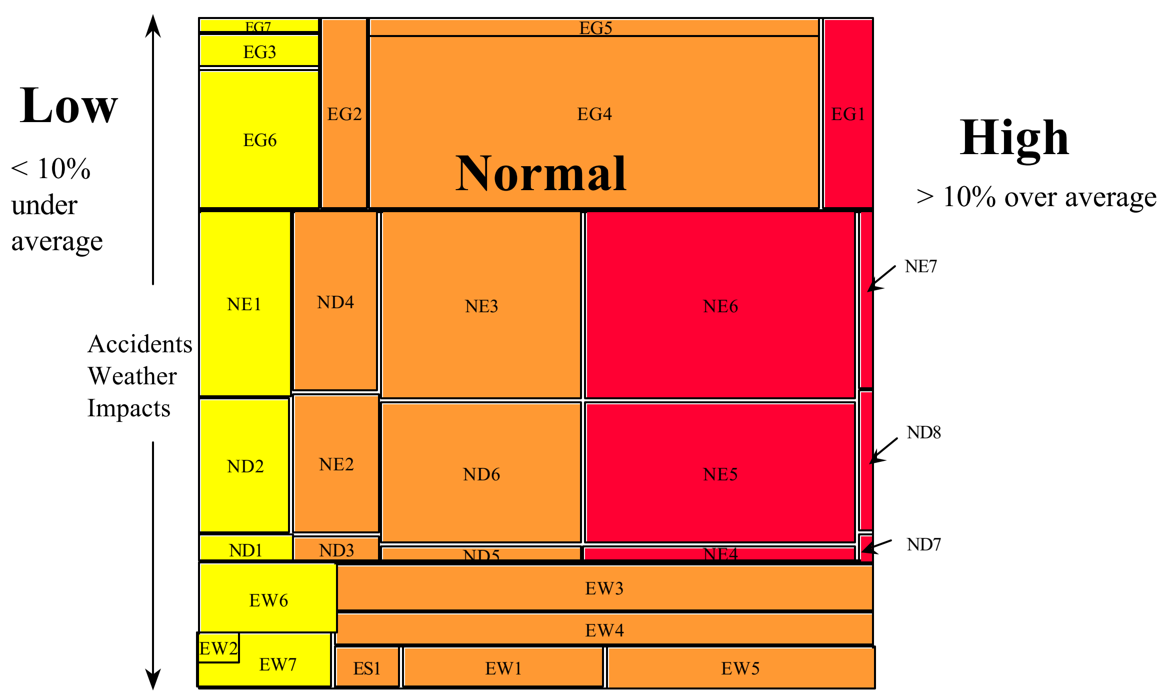
Low
< 10% under average
Accidents Weather Impacts
EG7
EG3
EG6
EG2
EG5
EG4
EG1
Normal
High
> 10% over average
NE1
ND4
NE3
NE6
NE7
ND2
NE2
ND6
NE5
ND8
ND1
ND3
ND5
NE4
ND7
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EW3
EW4
EW2
EW7
ES1
EW1
EW5

We use this arrangement of scenarios to present the measures of effectiveness results for each run of the alternative. Our results confirm the hypothesis that ITS is most beneficial when conditions deviate from the norm. (i.e. those scenarios at the edge). The highest levels of benefits occur for a number of measures of effectiveness studied in conditions of above average demand and major incidents. In these cases, the information on alternate routes, and the ability of the signal systems to respond to changing conditions provide the highest level of benefits to the most travelers. This will be further illustrated when the results are presented.

Measures of Effectiveness

During the study we discovered that additional measures of effectiveness were needed to properly represent the impact of ITS. A key phase in any MIS is the development of the measures that are used to evaluate the alternatives under study and that reflect the issues/concerns of those in the community making the decision. Typically, measures of transportation service, costs, mobility and system performance, financial burden, and environmental/community impacts are considered. These measures, however, are usually only calculated based upon the average weekday or expected conditions. Variation in conditions (e.g. travel demand, weather, accidents) and the transportation system's response to them is not part of the analysis and consequently does not enter into the decision process. However, incorporating variation in conditions is key to showing the benefits of ITS and other strategies focused on improving the operation of the system. Accordingly, in the study, several new measures were developed that are more representative of the impacts of ITS. *Delay reduction* is calculated as the difference between the travel time in each scenario and free-flow (30% of average demand, no accidents in the system, good weather) travel times. *Throughput* measures the number trips starting in the time frame that can finish before the end of the peak period at 9:30 AM. Delay reduction and throughput measures are calculated for each scenario. An annualized figure is then calculated by computing a weighted average of across all scenarios. System *coefficient of trip time variation* is calculated by examining the variability of travel for similar trips in the system taken across all scenarios. This statistic is an indicator of the reliability of travel in the corridor. Speed and stops across the network are archived from each run from the whole AM peak period. Speed profiles are then normalized by total vehicle-kilometers of travel in the system to create the statistic *percentage of vehicle-kilometers of travel by speed range*. A similar technique is applied to stops estimated by the simulation at a link level every 15 minutes producing an *expected number of stops per vehicle-kilometer of travel*.

Pair-wise Results

The Alternatives Evaluation section of the report contains a series of summary and detailed tables that provide a pair-wise comparison of alternatives. The summary tables provide descriptive information while the detailed tables provide the full range of both regional and sub-area MOE's. The specific set of comparisons provided in the report are indicated in Table ES-1.

Table ES-1. Alternatives Comparison Overview

Section	Pair-wise Comparison	
9.1 and 9.2	Baseline vs. Validation Network	ITS Rich vs. Baseline
9.1 and 9.3	SOV vs. Baseline	SOV vs. SOV + ITS
9.1 and 9.4	HOV vs. Baseline	HOV vs. HOV +ITS

The following paragraphs will discuss some of the results from one of these comparisons, the SOV alternative.

SR99, which parallels I-5, is both an undivided arterial and a limited access freeway. Under the SOV Capacity Enhancement alternative, a significant portion of SR99 near the Seattle CBD is converted into a limited access expressway. Table ES-2 summarizes the SOV Capacity Enhancement alternative without and with ITS improvements. These alternatives are characterized with respect to the 2020 Do-Nothing/TSM (Baseline) alternative. The SOV alternative is characterized at the regional level as providing faster travel times, particularly for trips that utilize the upgraded SR99 facility. At the sub-area level, the upgraded SR99 facility demonstrates susceptibility to congestion under weather or heavy demand cases. The result is that an expected improvement in annualized throughput and travel time <u>is not</u> realized. The SOV + ITS alternative mitigates to some degree the congestion conditions along SR99 under poor weather and heavy demand conditions, and provides a significant increase in annual sub-area throughput. At the regional level, the ITS improvements increase total trip length and bring additional demand into the sub-area.

The predominant trends at the regional level resulting from ITS enhancements to the sub-area, are relatively small in magnitude given that the sub-area where ITS implementation is proposed is a small subset of the region as a whole. Impacts on trips traversing the sub-area, however, are significant. Regional trends from implementing ITS, given the SOV enhancements, include a shift from auto modes to transit (0.73%), an increase in sub-area vehicle trips (0.72%), a decrease in regional vehicle trips (-0.30%), and an overall shift toward longer trips.

Some specific annualized MOE's drawn from the simulation sub-area analysis are provided in Table ES-3. Impacts of the SOV + ITS alternative are illustrated as *delay reductions* with respect to the SOV Capacity Expansion alternative. On an annualized basis, average traveler delay is reduced by 2.2 minutes per traveler per day, from 13.86 to 11.65 minutes per traveler per day. On an annualized basis, *throughput* in the SOV + ITS alternative increases to 185,565 vehicles per AM peak period (6:15 – 8:30 AM trip starts) from 168,338 vehicles. This increase of roughly 13,223 vehicles per peak period represents an increase in throughput of 10.2%. The coefficient of trip-time variation in the SOV alternative is 0.39. Applying this to a trip with an expected duration of

Table ES-2. Alternatives Comparison Summaries: SOV without ITS vs. SOV with ITS

2020 Alternative Comparison Implications SOV Capacity Expansion With ITS versus Without ITS		
Measure of Effectiveness	Impact of SOV WO ITS from NoBuild/TSM (Base)	Impact of SOV W ITS from SOV WO ITS (ITS Alt.)
Alternative Summary		
Regional Travel: Trips, Mode Choice, Times, and Miles Traveled		
Daily Travel		
	Overall daily person trips remain the same Shift to walk to transit trips within/from the corridor, but drop in long distance transit Park&Ride Drop in trips within study area and increase in trips to/from the subarea especially to CBD Increase in Daily V	Overall daily person trips remain the same Increase in transit person trips (slightly less than ITSRICH increase), and concomittant drop in vehicle trips Further reduction in within subarea trips and increase in trips to/from subarea. Additional increase
AM Peak Period Travel		
AM Travel	Similar patterns as found in daily travel Slight shift in overall transit results from higher walk-to-transit and drop in longer drive-to-transit Much faster travel in SR-99 corridor causes overall decrease in travel times	Similar patterns as found in daily travel Increase in transit trips but again slightly less than seen in ITSRICH Overall increase in travel conditions seen by slightly longer trips in transit and vehicle trips, and improved times, speeds
Subarea Trips	Significant increase in vehicle trips to/from/through the subarea due to diversion to SR-99 Improvements in SR-99 cause increase in subarea average speeds	Additional vehicle trips diverted to the corridor are the greatest of any alternattive Slight improvement in congested speeds due to more reliable system
Sub Area Impacts: Delay Reduction, Reliability, and Level of Service		
AM Peak Period Travel		
	Higher system demand Significant increase in travel time variability Throughput increase not concomitant with demand increase	Significant improvements in travel time variability and system throughput Changes particularly signficiant in weather or high demand scenarios
Capital & Operating Costs		
	Cost drivers are: Conversion of 14 miles of urban arterial to urban expressway Construction of nine new urban expressway interchanges Construction of nine new grade separated arterial crossings of the expressway	Capital costs to implement same elements as in ITS Rich slightly higher than for baseline due to increases in communications and traffic management costs.
Environmental Impacts		
	Likely marginally worse: increase in high-speed stops	Likely positive: many fewer high-speed stops

Table ES-3. Selected Sub-area Impacts: SOV vs. SOV + ITS

Measure per Average AM Peak Period, North Corridor Sub-area	SOV	SOV + ITS	Change	% Change
Delay Per Vehicle Trip (min)	13.86	11.65	-2.21	-15.9%
Vehicle Throughput (finished trips)	168,336	185,565	+17,227	+10.2%
Coefficient of Trip Time Variation	.39	.30	-0.10	-24.5%

60 minutes (normally distributed), a traveler would have to budget just over 99 minutes to arrive at the trip destination on-time 95% of the time. In the SOV + ITS case, the coefficient of trip-time variation is reduced to 0.30. Under the constraints of our example one-hour trip, the same traveler would have to budget 89 minutes to arrive at the trip destination on-time 95% of the time.

Figure ES-6 illustrates the conditions where the addition of ITS was most effective in terms of absolute minutes of delay saved per traveler. The largest delay reduction occurs in scenarios with incidents on SR99 (EG2) or I-5 (EG1), heavy demand scenarios (NE4, NE5, NE7, ND7, ND8), and weather/accident combination scenarios (ES1 and EW4).

The reason for ITS having a large impact in this case is that the SOV Capacity expansion alternative and the upgrade SR99 expressway facility can each be characterized as having "brittle" performance. When travel demand is close to average conditions or lighter than average and weather conditions are clear, the new SR99 expressway facility efficiently handles traffic along its length, both in terms of through movements and traffic exiting at grade-separated interchanges with the adjacent arterial grid. Travel times in these cases are improved for trips that typically use SR99. When the travel demand is high or capacity is reduced from weather impact, the upgraded SR99 facility's performance breaks down to a point that travel times actually exceed those associated with the pre-upgrade signalized arterial facility.

SR99 Expressway breakdown is a function of the narrow right-of-way accorded the new facility. The number of opportunities to exit the upgraded SR99 expressway facility and access the adjacent arterial grid are reduced since only a subset of the signalized intersections along its length have been converted to grade-separated interchanges. This results in high off-ramp utilization along SR99. Reliance on these off-ramps becomes problematic because they are relatively short and end with signals. These short ramps cannot hold many vehicles attempting to exit SR99, and if signal controllers at their terminus are set to relative long cycles, then we see periodic queue spillback into the expressway facility. The simulation model accurately reacts by severely crimping expressway carrying capacity when this condition occurs, resulting in backups in the SR99 expressway mainline. These periodic breakdown become persistent breakdown conditions when travel demand is high or under poor weather scenarios.

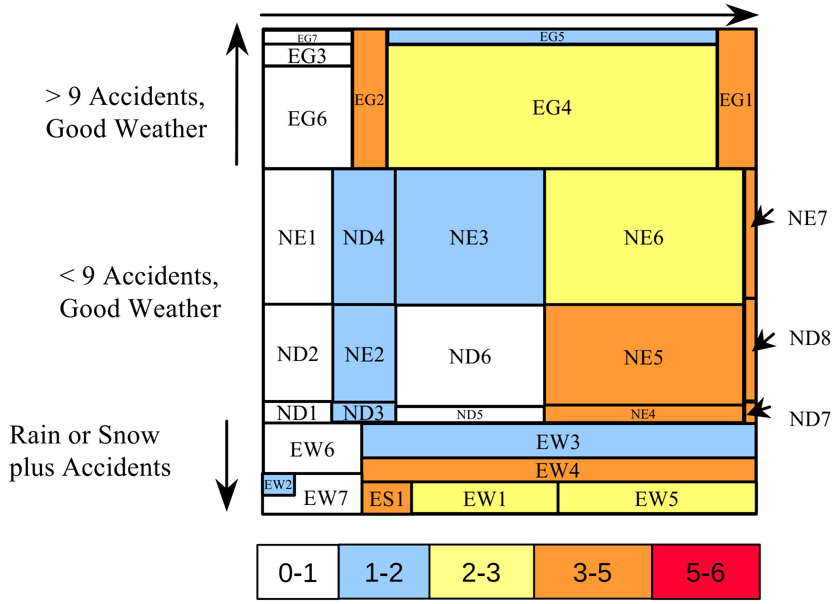

Figure ES-6. Minutes of Delay Reduction: SOV + ITS vs. SOV

ATMS control as implemented in the SOV + ITS alternative helps to mitigate the impact of SR99 breakdown. In these cases the adaptive signal control system senses the queue buildup on the off-ramp and extends the ramp's green phase to flush vehicles off of the ramp/mainline and onto the arterial grid. The minor arterials see worsened service as the green phase for the off-ramp is progressively extended, but from a system perspective, keeping the SR99 mainline from breaking down is the most critical factor in reducing overall delay.

Similar results are provided in section 9.0 of the report for the comparison of the ITS Rich alternative to the Baseline, and the comparison of the HOV/Busway alternative with and without ITS to the Baseline. Also, in this section detailed results for all the MOE's are provided.

Observations on Alternatives Analysis Results

Key attributes of how an alternative might perform under expected travel conditions (such as the brittleness of the SOV alternative) could not have been predicted using only the regional model. Under normal conditions, the SOV alternative appears to have ample capacity at the SR99 interchanges. Since the regional model does not consider the periodic queue growth from traffic signals or spillback, a breakdown along SR99 does not occur. Clearly there are non-ITS solutions to the off-ramp problem: wider right of way at interchanges, revised interchange design, more interchanges, etc. However, it is likely that *these issues would not have been addressed until the engineering design phase of the alternative*. Knowing at the <u>planning phase</u> that the new SOV facility had this performance characteristic is a critical element to either tailoring the alternative definition or in the comparison of alternatives.

Potential Next Steps

The goal of the study was to develop and demonstrate the use of a new methodology for incorporating ITS into the transportation planning process. We feel that the methodology developed (PRUEVIIN) and the alternatives-analysis results contained in this report met this goal. The ITS cost and benefit results provided herein are a significant addition to the store of ITS knowledge. The PRUEVIIN methodology and the study results have been presented at several conferences and at the *Workshop on Methods to Model ITS Impacts* during the 78th Annual Transportation Research Board (TRB) Meeting.

There are several next steps for further use of this report and analyses using this methodology, each of which is discussed below. These include conversion of this report into more of a user-guidance document, development of a training course to teach the methodology, and the direct application of the methodology to an ongoing MIS.

This report documents a three-year analytical effort. It provides richly detailed documentation on methodology, and ITS cost and benefit results. However, it has some limitations. The document is written as a report on the results of a study effort. It is not written in the form of a users manual, providing comprehensive, ordered, guidance to a transportation planner who is interested in the implementation of this methodology to achieve similar results in his/her region. In addition this process was implemented in only one location (Seattle, Washington), and with only one planning model (EMME/2) and one simulation model (INTEGRATION 1.5). The set of ITS Rich technologies was also fixed for the study. In addition, this study was done with the knowledge of and cooperation of PSRC, the local Metropolitan Planning Organization (MPO). They participated at the front-end of the study and reviewed the results at the end of the study. However, they were not involved in the actual execution of the study or in the refinement of the alternatives as the study progressed. The study is for a "shadow MIS," not an actual MIS. We followed the MIS approach in terms of alternatives development, definition and impact measures, but were not constrained by the need for public hearings and review of alternatives.

With these facts in mind, Mitretek recommends that the best way for transportation professionals to learn this methodology would be for them to receive some hands-on training. This could be achieved by having an organization that is knowledgeable in the PRUEVIIN methodology to act as technical advisor to actually add a sub-area simulation as described in this study to an ongoing MIS. This would accomplish several objectives including: the individual staff at the transportation agency would have first-hand experience with using the process, the process would be left in-place at the agency for further studies, and the training organization would then be in a good position to write a user-guidance document for the methodology. In addition, additional knowledge would be gained by applying this process in a new environment, i.e. different problem set, alternatives, and models.

An additional approach would be for Mitretek to work with the ITS JPO to develop one or more training courses for the process. Mitretek would develop and give the course for the first several iterations. This will allow us to refine and tailor the presentation material to the transportation professionals in the various transportation agencies. Afterwards the course would be turned over to a professional training organization for wider audience presentation.

1. Introduction

1.1 Study Background

As more Intelligent Transportation Systems (ITS) capabilities become ready for deployment, they will need to be integrated into the established transportation planning process. This process involves analysis of costs, benefits, and choices among competing projects within financial and other constraints. ITS components will in many cases be combined with more conventional transportation components as part of an alternative to address a specific transportation problem. Considering ITS in the transportation planning process raises many questions about how to select and evaluate ITS projects as an integral element of traditional transportation construction projects.

In addition, the current state-of-the-practice for transportation planning does not include well-developed tools or techniques for quantitatively assessing ITS benefits, because ITS itself is new, because operational aspects are important in assessing ITS benefits but are not traditionally considered in planning studies, and because ITS planning tools and methods are still evolving. Consequently, good analytic tools for assessing ITS costs and benefits are lacking and transportation planners may have less experience with ITS compared to other types of transportation improvements. In light of these considerations, any approach to study these issues would have to include:

Reviewing existing evaluation procedures and developing a quantitative investment analysis methodology for ITS for state or local use in transportation planning.

Developing case study-based estimates of relative costs and benefits of ITS versus conventional investments.

Identifying needs for improved methods project identification and evaluation.

To address these questions the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) of the United States Department of Transportation (USDOT) tasked Mitretek Systems to investigate the incorporation of ITS into the transportation planning process. To accomplish this Mitretek initiated a two-phased study effort, conducted over two years. An important goal of the ITS JPO is the consideration of ITS by transportation planners. This study develops a methodology for public sector investment analysis to analyze ITS investments, and to develop case-study based estimates of relative benefits of ITS infrastructure investments versus conventional transportation investments. The secondary study objective was to identify improvements for the analytic tools and methods.

The analysis in phase 1 studied how ITS leaders planned and deployed, exploring their methods and processes. Phase 1 reviewed the current process of prioritizing projects, examining how different regional transportation problems and needs are addressed in the Transportation Improvement Program (TIP) approval process. The analysis in phase 2 focused on the evaluation of alternative solutions to a given transportation problem. These alternatives could be incorporated, depending upon evaluation results, into the Transportation Plan and eventually the TIP. An example of this type of analysis is the approach taken when conducting a Major Investment Study (MIS). This second type of analysis is the focus of this report. Mitretek initiated phase 1 of the study in 1995 on how ITS projects were evaluated and included in a major transportation improvement program (TIP).to address ITS deployment. For this phase existing practices in two regions, Houston, TX and Seattle, WA were studied. Phase 1 focused on the prioritization process in Houston and Seattle, and identified several factors in the project evaluation process. Briefly, the conclusions reached include:

1. Planners should consider additional qualitative and quantitative factors along with traditional ones, when evaluating ITS projects, beyond those traditional factors typically found in a scoring process These additional qualitative factors include:
    a) ability to respond to and manage traffic incidents and changing traffic situations,
    b) ability to provide transportation system users with a new or improved level of service (including customer satisfaction)
    c) ability to support multiple uses for the transportation system or across different agencies, including the ability to provide planning data.
2. The additional quantitative factors that should be considered include:
    a) ability to generate cost savings (or revenue increases) to public transportation agencies.
3. ITS project funding sources should be considered, including funds allowed by federal rules and funds available from local and other sources. Planners should not artificially constrain ITS funding sources to specific, or narrow categories, such as CMAQ.

Phase 2 of the study started in July 1996, focused on the greater Seattle metropolitan region, and developed specific methodologies for the evaluation of ITS project alternatives in the context of an MIS. The results of this phase of the study are the focus of this report.

1.2 Use of Case Study Approach

Mitretek took the approach of conducting a case study rather than relying on a hypothetical transportation network. Specifically, we selected a sub-region or corridor in the Seattle area suitable for analysis. That is, a corridor where alternative solutions to a particular transportation problem could be developed, and where a variety of ITS strategies and traditional transportation improvements were applicable.

For illustration, if the problem to be addressed is congestion along an urban corridor, the list of alternative solutions might include "do-nothing", construct a new road, add lanes to existing routes, provide HOV lanes, provide ramp metering, provide incident management systems, add bus or light rail service, as well as combinations of these listed capabilities. In this study ITS services were analyzed separately and in combination with conventional construction options.

Mitretek examined the alternative solutions for the Seattle study area, in close coordination with the transportation consulting firms Parsons Brinckerhoff Quade Douglas and CH2M Hill. The study team adapted and extended conventional transportation improvement modeling and impact analyses to be more sensitive to the impacts of ITS, and to provide for comparability of outcomes across the evaluated alternatives. The analysis methodology developed and its results were reviewed with Seattle region planning staffs during the study to assess the appropriateness and usefulness of the Mitretek approach.

1.3 Scope of This Study

This study covers: delimitation of the study area, identification of transportation problems, description of the alternatives considered, explanation of the specific analysis approaches, and examination of the results from applying these analysis approaches. We chose to evaluate several traditional transportation alternatives in the corridor, with and without ITS components. Simulation modeling and other analytical techniques were applied to these selected cases to quantify benefits and assess the alternatives against a common set of measures of effectiveness (MOEs).

The phase 2 Seattle case study assumed that an MIS was needed as part of the transportation planning process to assess specific alternatives to solve a specific transportation problem in the Seattle area. This study examines a corridor, rather than a single, traditional project. The geographic scale of the Seattle case study corridor is a sub-area of the Seattle transportation network larger than that associated with a single transportation feature (e.g., an interstate segment), but smaller than an entire urban region. This geographic scale parallels that prescribed in MIS guidance and allows for a variety of transportation alternatives to be considered and evaluated, without being so broad as to dilute the evaluation process with an intractable number of potential alternatives.

The range of transportation improvement alternatives considered in this study included construction of new roads or lane miles, conventional signal installations, transit improvements, Transportation Demand Management Systems, Advanced Traveler Information Systems, Advanced Traffic Management Systems, and Advanced Public Transportation Systems. The study did not consider Automated Highway Systems or Commercial Vehicle Operations.

The analysis tools required for ITS evaluation in the case study were compared to conventional transportation improvement planning and regional planning tools. Recommendations are made for adoption of the analysis methodologies outlined in this report in the transportation planning process and evaluation issues requiring further work are also identified. The results of specific Seattle-based simulation runs are documented in this final phase 2 report.

It is important to contrast this study with another recent work. “The Interim Handbook on ITS Within the Transportation Planning Process” (FHWA, Transcore, August 1997), a general reference, considers ITS as part of the ongoing planning, implementation, and operations activities for agencies involved in planning for and providing transportation systems and services. The Interim Handbook provides a thorough discussion on how ITS should be considered in transportation plans and improvement programs, corridor/subarea studies, and regional or statewide ITS strategic assessments. The handbook also provides reference sections on cost estimating and sketch planning techniques to evaluate ITS strategies. Except for the section on corridor/subarea studies, these topics are not the focus of this report. The work presented here goes beyond the material presented in the handbook by developing and demonstrating a structured problem identification and alternative definition process and a specific evaluation methodology for including ITS in a corridor study.

1.4 Report Organization

This report is organized into three primary parts. In the first primary part, three sections provide background information that frames the work done for the Seattle case study. Section 1 provides background information on the study. Section 2 discusses the planning context for corridor/sub-area studies and the evaluation techniques typically used in such studies. Section 3 discusses the challenges involved with including ITS alternatives in these studies.

In the second primary part of the report are the specifics of the Seattle case study. Section 4 presents the characteristics and objectives of the case study as well as an overview of the approach. Section 5 discusses the selection of the study corridor and the corresponding transportation needs and problems addressed. The set of transportation alternatives defined and evaluated in the case study are presented in Section 6. The analysis framework and approach to evaluating the alternatives is covered in Section 7. Section 8 documents the procedures and results of the process to validate the models employed in the case study. Section 9 presents the results from the analysis of the alternatives and Section 10 presents lessons learned.

2. Corridor Planning Studies

2.1 Introduction

This section presents corridor or sub-area planning studies in the context of the overall transportation planning process and discusses the evaluation methods typically used in such studies (for the remainder of this report, "corridor studies" refers to both corridor and sub-area studies). The inclusion of ITS strategies is facilitated when considered within the framework and characteristics of each different type of planning study. For any particular study, the level of detail and effort involved in defining and evaluating ITS alternatives should be consistent with that involved in defining and evaluating more traditional transportation alternatives. This section will help to frame the discussion of evaluation challenges in the next section and the specific procedures used in Seattle case study, presented in Sections 4 through 10.

"A Guide to Metropolitan Transportation Planning Under ISTEA" (U.S. DOT 1995) presents and discusses the general planning framework that ITS needs to be considered within. Corridor/sub-area planning studies, which is the focus of this report, are considered to be part the long range planning process, leading to transportation plan adoption. Where the planning process identifies a corridor or sub-area that suggests the possible need for a major investment using Federal funds, then a Major Investment Study (MIS) may be required. Figure 2-1 shows MIS within the Transportation Planning Process.

MIS and its requirements were defined as part of joint FHWA/FTA Final Rule on Statewide and Metropolitan Planning (FHWA & FTA, Federal Register, 10/28/93) to implement the concepts of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). MIS provides a common multi-modal evaluation process to follow[1] and a tool for making better more informed choices over major transportation decisions facing an urban area. The transportation planning process in general examines regional travel patterns, needs/problems, and potential solutions at a systems level usually at relatively broad detail. Where corridor major investments are contemplated, however, there is a need to provide a more focused finer analysis than possible at the regional level of analysis to fully understand the corridor's problems and tradeoffs among it's alternatives. MIS provides the focused examination of the causes of the corridor's mobility needs and related problems and the impacts/costs of solution alternatives. As such, "The MIS is an integral part of the metropolitan area's long-range

[1] Previously the FHWA and FTA both had separate requirements for a project requiring a major investment to follow. Which was relevant depended on the project's major mode (transit vs. highway) and funding source.

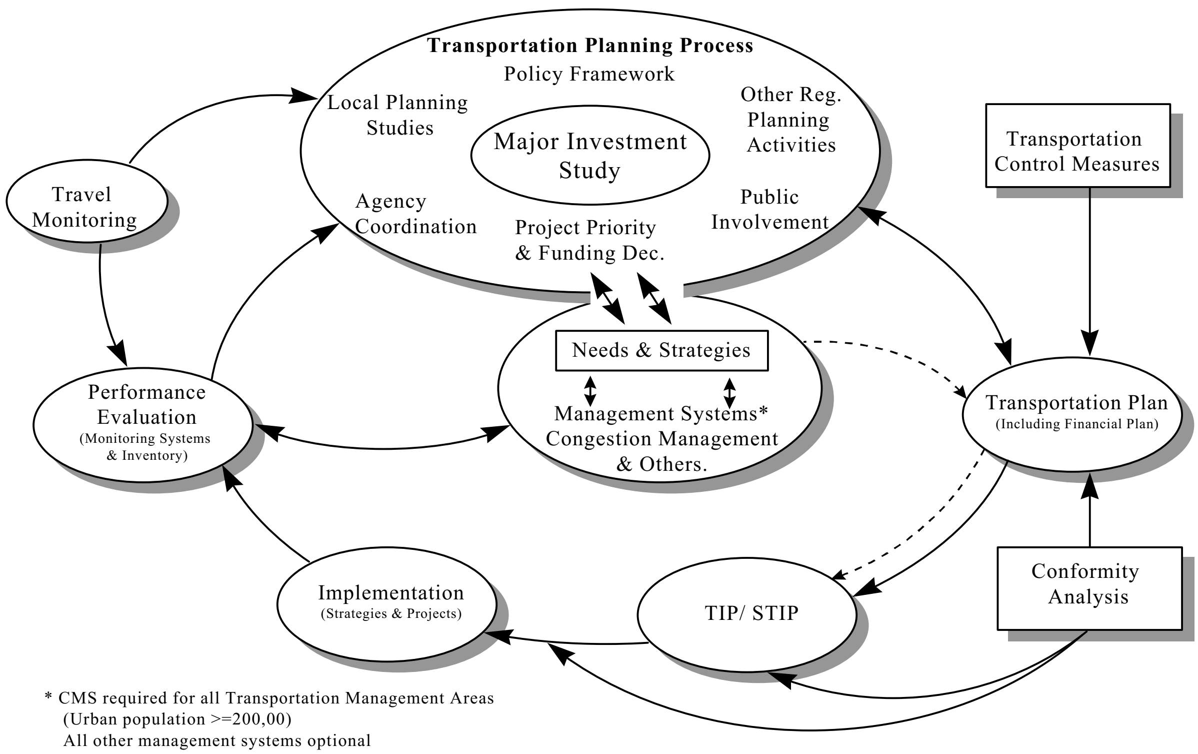

Figure 2-1. MIS and the Transportation Planning Process

planning process that is designed to provide decision makers with better and more complete information on the options available for addressing identified transportation problems before investment decisions are made." (National Transit Institute, Parsons Brinckerhoff Inc., 1996, p. 1-1).

An MIS is required any time the metropolitan planning process considers alternatives that may be characterized as:

> a high-type highway or transit improvement of substantial cost that is expected to have a significant effect on capacity, traffic flow, level of service, or mode share at the transportation corridor or sub-area scale (Statewide Planning: Metropolitan Planning: Final Rule, FHWA & FTA, Federal Register, 10/28/93), and where Federal funds are potentially involved.

Examples of a "major investment" include the construction of additional lanes, a new facility, or a new light-rail line.

Each of the major components/products focuses on a different aspect, set of concerns, and level of decisions in the overall transportation planning process. Consequently, each component may require varying levels of detail, information, time horizons, or analysis turn around to meet its needs. For example, as already stated, MIS studies provide a detailed evaluation of the transportation needs and major investment options in a corridor or subarea. They look at a long range (20 year) time horizon, and may take several years to complete. How MIS relates to each of the components is briefly discussed below. While the major focus of this study was to examine ITS within the MIS process, ITS may play an important role at each point in the planning cycle. At each point the issues and concerns of incorporating ITS may also differ. Some of these issues are also highlighted below.

The Transportation plan sets the long term agenda and direction of the transportation system in a region. Since it must be financially constrained it reflects the funding priorities and tradeoffs between projects and corridors. The plan typically focuses at a regional scale examining projects of "regional significance" and the major transportation policy directions of the region. The transportation plan's inputs include local planning studies and other regional planning activities (land use, environmental, growth, etc.), and the results of special efforts such as MIS studies, and Congestion Management System (CMS) plans. Key elements in developing the transportation plan also include the policy framework and goals of the region, inter-agency coordination and public involvement to determine project priorities and funding decisions. The adopted constrained long range plan plays a critical role in MIS studies since it is used to establish the Do Nothing Alternative, especially outside the corridor under investigation. Equally important to MIS studies considering ITS is the determination of the core ITS "center systems" that serve across corridors or even the region as a whole (i.e. the ITS regional architecture/framework). Once an MIS study is carried out the transportation plan must be amended to include its preferred plan and the new plan shown to conform to the State Implementation Plan (SIP) for air quality (see conformity analysis below). Thus, the transportation plan and MIS studies are codependent, both feeding information to each other.

Congestion Management Systems (CMS) are required for all Transportation Management Areas (TMAs)[2] and are optional in smaller areas. The CMS principles are "designed to emphasize effective management of existing facilities through use of travel demand and operational management strategies", and analyze the entire transportation system's performance not the performance of any one specific mode (FHWA & FTA, 1995). CMS have two major components. The first is the definition of system performance measures, their measurement, and continued monitoring. The second is the identification and implementation of strategies that provide the most efficient and effective use of existing and future transportation facilities. Thus, CMS are operations oriented. Though they have a future component they are also typically geared towards the near term, collecting data on and evaluating today's problems and evaluating strategies implemented to solve them.

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[2] TMAs are defined as urbanized areas with population greater than 200,000.

ITS can play a major role in CMS plans, both in data collection and in management strategies. In fact, ITS technologies are one of the five key categories explicitly listed in the FHWA/FTA Management and Monitoring Systems: Final Rule[3] (FHWA & FTA, Federal Register, 12/19/96).

MIS studies and the CMS plan also have a reciprocal relationship in their support of each other and the Transportation plan (See Congestion Management Newsletter, V. 1#3, FHWA, March, 1995). CMS helps define the needs and problems in a corridor that trigger the requirement for an MIS. More important, the CMS may help understand the causes of a corridor's transportation needs and congestion and therefore help frame the MIS problem statement. MIS on the other hand, can be used to examine alternatives and provide information helpful for assessing strategies to reduce congestion in the CMS. In air quality non-attainment areas both can assist in the required analyses to justify the need for proposed Single Occupant Vehicle (SOV) capacity increases.

The shorter term **Transportation Improvement Program (TIP)** provides the project prioritization and selection for the next three years (and optionally longer). It must be updated every two years. All project elements that will be initiated (begin construction and/or operation) within the TIP time frame and receive Federal funds must be included in the TIP. Projects in the TIP must be consistent with the transportation plan and include both details and programming for the regionally significant projects specifically called out in the plan, and non-regionally significant projects. The specific projects are defined, prioritized, and programmed for project development/implementation in the TIP process. The preferred alternative from an MIS is first reflected in the transportation plan. Then as the implementation of the alternative nears and begins its specific elements (traditional and ITS) must also be prioritized and programmed in the TIP. For a discussion of issues associated with incorporating ITS elements in the TIP project prioritization and programming process please refer to "Incorporating ITS into the Transportation Planning: Phase I Final Report" (Mitretek Systems, September 1997).

Environmental analyses include the State Implementation Plan (SIP) **Conformity Analysis,** and **National Environmental Policy Act (NEPA) process.** An MIS preferred alternative must be part of SIP conforming transportation plan for final approval. This means that a conformity analysis is usually required as the plan is updated to include the MIS results. The MIS process also provides a bridge to the NEPA process and must be carried out with careful consideration of the NEPA Environmental Impact Statement requirements[4].

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[3] Growth management and congestion pricing; traffic operational improvements; public transportation improvements; ITS technologies; and where necessary, additional system capacity.

[4] Either as a pre-cursor study prior to the NEPA documentation process (Option 1), or in tandem with the NEPA process (Option 2). For more information, refer to the Desk Reference Manual for MIS (National Transit Institute, Parsons Brinckerhoff Inc., 1996).

One issue that cuts across all phases of the above transportation planning process is the requirement to include only regionally significant, and/or federally funded projects. Locally funded projects with localized impacts may, or may not be documented as part of the federally required plans and documents. Consequently, many ITS and other operational projects have often not been included historically within the planning process. These include such improvements, as traffic signal upgrades, transit vehicle and other operational improvements, information systems, etc. How these off plan ITS and other improvements can be used to enhance alternatives in MIS and the system in general must be considered in the process if the full benefits of the ITS are to be reflected in a region's transportation plans and MIS efforts (see Mitretek, September 1997).

For more information on the overall process, ITS in the planning process, and non ITS related MIS details, refer to: "A Guide to Metropolitan Transportation Planning Under ISTEA" (FHWA & FTA, 1995); the Desk Reference Manual for MIS (National Transit Institute, Parsons Brinckerhoff Inc., 1996); and "Integrating Intelligent Transportation Systems within the Planning Process: An Interim Handbook" (FHWA, TransCore , August 1997).

2.3 Supporting Analysis

As discussed above, transportation planning is a continuous process with many decision points and is intended to provide a sound environment for analyzing transportation investment and policy alternatives and allocating transportation resources in a way that best addresses the transportation needs and problems facing an area. To support the decisions that must be made within the planning process, a wide variety of analytical techniques are used to provide estimates of the potential transportation impacts and costs of alternative investment strategies. At each level of the process the appropriate analysis techniques differ in level of detail and effort required to use them (translating to the amount of resources required) depends on a variety of factors including:

- the scale and level of anticipated impacts of the decision (both geographic and costs)
- the number of alternatives
- the project time frame
- the decision time frame
- the phase in the project development cycle (concept, scoping, development, design, construction, operation).

Usually, less rigorous evaluation approaches are sufficient to support early, screening-type decisions (occurring early in the planning process) and more rigorous and detailed approaches and tools are desirable to support decisions with higher investment implications (either later in the planning process or for establishing a preferred alternative that will be considered a major investment to be folded into the transportation plan). For example, regional analyses using "planning model network tools" and representing "regionally significant" projects are usually used to support the transportation plan and its conformity analysis. Due to the long time-frame of the transportation plan these analysis techniques attempt to capture the major changes in travel patterns and location decisions, introduced by major options in a region's future transportation system. As already stated, MIS analyses perform much a much more detailed examination of the impacts of alternative decisions within a corridor or sub-area. Their goal is to distinguish between the options to solve the corridor's need and problems statement, and assist decision makers in making a preferred choice. The level of investment decision, issues to be resolved, time schedule of a typical MIS usually allow fairly complex and detailed analysis procedures to be carried out. On the other hand, TIP and CMS analyses must select from a wide variety of projects and strategies, usually with a short analysis and decision time period. Sketch techniques that can be used to evaluate a number of alternatives quickly capturing localized effects and pivoting off of current (near term) conditions often suffice for these analyses.

A thorough discussion of all possible analytical approaches is not covered here. However, it is important to keep in mind the general types of techniques that apply. Analytical techniques and tools used in planning studies generally fall into these major categories (presented in general order of increasing complexity and data requirements):

> Qualitative assessment - relies on previous experience or expert judgment. These assessments are used everyday by project managers in selecting the candidate projects for further investigation, and making quick evaluations.
>
> Sketch planning techniques - generally straight-forward, parametric, or spreadsheet analyses that provide an approximation of potential impacts (may rely on historical data). These are often used when there is a large number of options to evaluate, the impacts are localized, or the individual projects relatively small. They are also used to screen an initial set of alternatives to likely candidates for further study.
>
> Planning models - models that forecast average (steady-state) travel and transportation demand and associated impacts over a given time period (daily, peak period, etc.), typically using some variant of the four-step method (trip generation, trip distribution, mode split, and assignment) with inputs from demographic and land-use projections. These tools are used to capture long range impacts of transportation system changes at the regional level. They are also often used with refinements and additional detail for MIS and other more focused studies.
>
> Simulation models - models traffic flow and interaction with the network in more detail (e.g., signals are explicitly modeled), allows for time-variant travel demand and introduction of incidents or other non-recurring traffic events. Simulation tools may provide key inputs to a project's design and/or operation that cannot be addressed using other tools.

This study focuses on the analysis requirements of a corridor/sub-area planning study. In practice, many of these studies are likely to be Major Investment Studies (MIS). For this reason, MIS requirements and guidance provide the benchmark for the analytic approach pursued in the case study. Although the level of analytical detail varies based on the decision to be made and the ability to distinguish between options, network-based planning models are typically used to forecast the transportation demand and impacts under the different alternatives evaluated in an MIS. An MIS will often include enhancements in network coding and analysis detail, not used in the regional level transportation plan analysis. This level of detail enables some of the differences and implications of alternative investment strategies to be brought out and discussed by the decision makers, which is important when the costs and impacts of the potential investment are significant. These models usually incorporate the traditional four-step method (trip generation, trip distribution, mode split, and assignment) in the analysis framework. As will be discussed in detail in Section 7, this study adds a simulation model in order to incorporate ITS strategies into the analysis at a level of detail required to fully capture the potential benefits of ITS services and to discriminate between alternatives.

3. ITS Considerations in Corridor Planning Studies

Section 2 examined the context for corridor planning studies within the overall planning process. This section focuses on the issues associated with incorporating ITS into these studies and highlights the Major Investment Study principles used to guide the development of the Seattle area case study selected for the project. Many of the issues are discussed in more detail in the sections of the report which describe the details of the case study.

ITS strategies to date have generally not been incorporated into current MIS processes[5]. This is due both to basic differences between ITS and traditional corridor improvements and to a lack of familiarity in many areas with the potential of ITS.

Traditional solutions to transportation problems and the analyses that support them have tended to focus on long term facility/service improvements to meet capacity constraints arising during a typical day. Because they focus on the peak congestion conditions and major infrastructure investments these solutions and analyses have typically minimized or not addressed:

> The impact of operational strategies and improvements. Current operations are usually assumed.
>
> The impact of non-recurrent demands, incidents, or other unusual occurrences. Major facilities are usually not designed to accommodate unusual demands, or events. Analyses focus on meeting average conditions.
>
> Lack of information about the system, its current condition and the choices a traveler may have in making their trip. Traditional analyses assume equilibrium conditions where travelers fully know their choices, their travel times, costs, and other characteristics.

However, as has recently been reported, non-recurrent accidents and other incidents are major contributors to urban congestion. One source estimated that up to 60% of congestion can be attributed to non-recurrent delays (Lindley 1986). Not including these effects in an analysis can consequently distort the impacts of traditional alternatives and overlook the benefits of ITS.

ITS strategies on the other hand use technology, communications, and a “systems” perspective to help adjust the system to conditions as they are realized on a day-to-day basis or evolve over a longer time frame. ITS Strategies are:

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[5] If they are included at all, it has usually simply been part of the Do Nothing or TSM base alternatives with little substantive analysis or refinement to support each build option.

Operations Oriented. ITS strategies such as coordinated signal systems, ramp meters, and automated toll readers directly impact the operation of the transportation system by reducing delays and adjusting the performance of the system as conditions change. They also provide the ability to manage the multi-modal components as a system instead of separate units. Traditional planning analysis efforts typically assume a steady state set of conditions over the analysis period and are consequently insensitive to changes in operations. More and more, however, it is being recognized that managing system-wide or subsystem operations may offer very cost-effective mobility improvements within a corridor comparable to traditional capacity expansion. Recognizing this, TEA-21 incorporates operational concerns into its list major planning factors that must be considered as part of a region's planning process.

Aimed at Events and Unusual Conditions. Non-recurrent incidents, special events, and weather conditions all add up to become significant factors in the delay and congestion found in our transportation systems. ITS strategies such as incident and emergency management systems, route guidance, highway advisory radio, and variable message signs, all help the system respond to these non-recurrent conditions. Yet, a typical analysis does not include incident occurrences in its validation of base conditions, and is based upon average, expected, conditions under "normal" conditions (i.e. no accidents, bad weather, or unusual conditions). It consequently cannot address the impact of incidents on the system or an alternative's ability to respond to them.

Information Oriented. ITS strategies focus on reducing the difference between a traveler's expectations of the transportation network while they are traveling (congestion, delay, and cost along each route choice) and the actual conditions they will experience when they take their trip. Traveler information systems provide more up-to-date information on accident locations, transit routes to take, cost, and other characteristics of travel options. Route guidance systems help the system operate more efficiently by routing traffic away from accidents and other occurrences of delay. As travelers and the system operators have better, more up-to-date information, significant improvements to an individual's choice can occur, especially under special circumstances. Typical analysis techniques presume that over the long run, travelers will "know" their options and make "informed" choices.

Connected Systems. ITS services are a mixture of localized elements and area-wide systems/intelligence. As communications and system intelligence/response is introduced through ITS, individual ITS elements no longer function or can be analyzed independently. Thus, the metered rate (capacity) of a ramp meter may depend upon the traffic volumes at downstream locations along a freeway, sometimes miles away.

Each of these characteristics makes ITS strategies difficult to address using traditional MIS analysis methods and measures of effectiveness and create implications throughout the MIS process. An overview of the MIS process in general and some of the issues incorporating ITS raises is provided next. This is followed by an examination of ITS in each of the major phases of the MIS process.

3.1 Overview of MIS Process

Figure 3-1 shows the major phases of a Major Investment Study (National Transit Institute, Parsons Brinckerhoff Inc., 1996). Once the need for an MIS in a corridor is identified[6] the major steps in a typical MIS process include:

Initiation, Problem Definition, and Development of Goals and Objectives (and their Measures) - the description of corridor problems and mobility needs is refined and the corridor goals and objectives that will drive the evaluation process are articulated.

Development of Initial Set of Alternatives.

Screening and Decision on Detailed Set of Alternatives.

Analysis, Refinement and Evaluation of the Alternatives - includes detailed definition of alternatives and service/operations planning, estimation of capital and operations and maintenance costs, transportation and traffic impacts analysis, land use evaluation, environmental impact analysis, and financial analysis.

Selection of a Preferred Investment Strategy.

Public and Agency Involvement - Throughout the MIS, and in particular prior to key decision points, the public is given the opportunity to comment and provide feedback on the study recommendations and the process being followed. MIS also requires close coordination between and within agencies and jurisdictions. State DOT, transit agencies, metropolitan planning organizations, and local jurisdictions all have a say in the scope of the study, range of alternatives, evaluation criteria, etc. Equally important with the introduction of ITS in the process is the need for planners and operations professionals within each agency to coordinate closely with each other where traditionally they have not. While critical to the success of the MIS process, public and agency involvement/collaboration is beyond the scope of the case study.

In order to be fully incorporated into the MIS framework, ITS strategies must be explicitly treated as an integral part of the steps and phases highlighted above. An important point that needs to be stressed up front is that ITS is an umbrella name for a suite of alternative strategies, rather than a single monolithic alternative, and includes a variety of traffic management strategies, transit applications, incident and emergency management services, and traveler information systems. The implication is that a variety of different ITS strategies

[6] Through the CMS, local planning, or other elements in the transportation planning process. See Section 2.

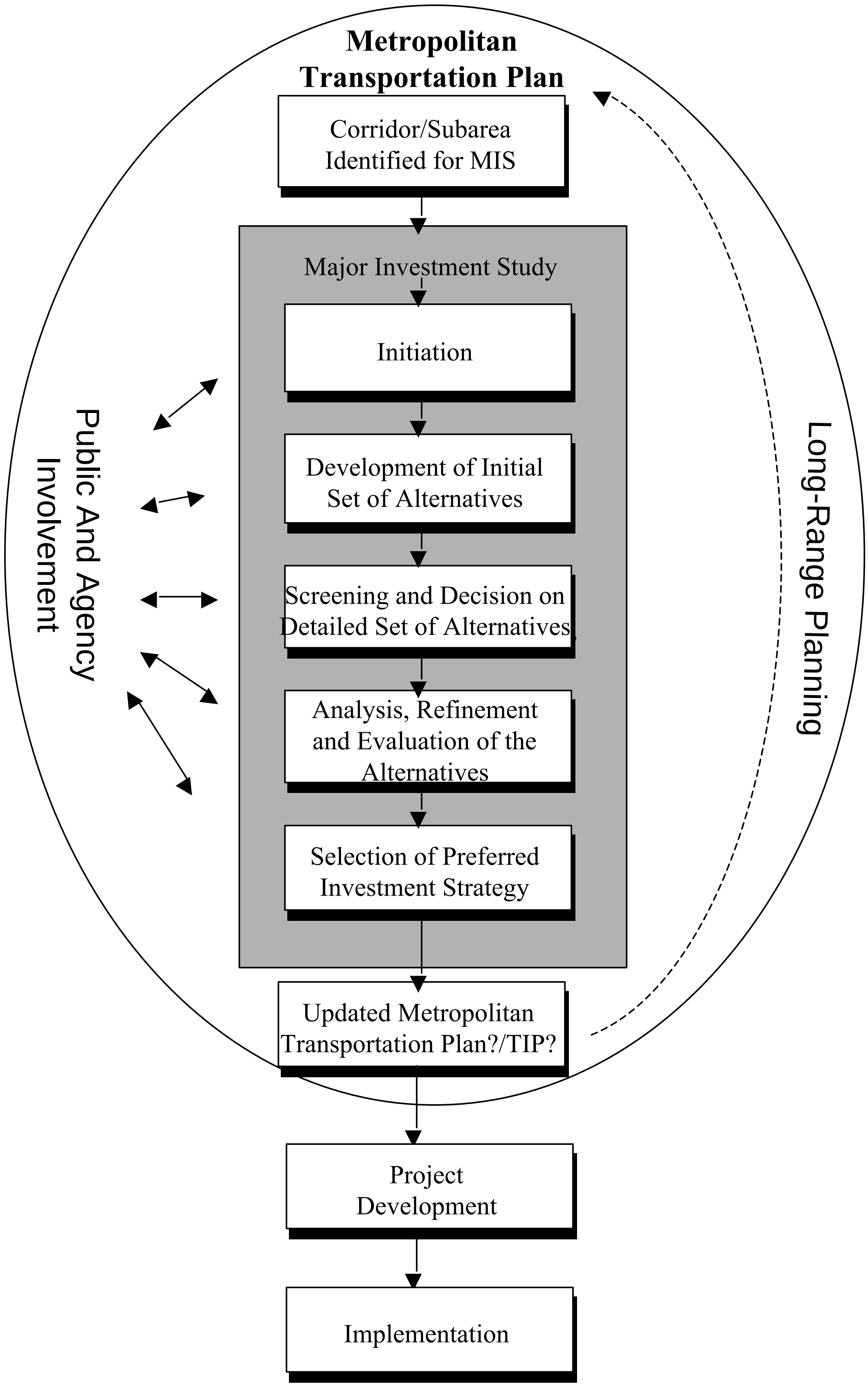

Figure 3-1. Major Phases of a Major Investment Study

can be included in a variety of ways in an MIS process. These different strategies may have very different evaluation requirements, as will be discussed later in the report.

Although the study team did not perform a thorough investigation of all previous and ongoing MIS efforts, anecdotal evidence suggests MIS studies are now just beginning to consider ITS elements in their study designs. Previous consideration of ITS in MIS alternatives has been somewhat limited ranging from none at all to inclusion of ITS in a TSM or separate enhancement package[7]. It appears that little has been done on how to how to enhance and maximize the efficiency of traditional build options. By including ITS in the baseline or in common TSM alternatives, some of the MIS efforts may be avoiding the need for thorough evaluation of ITS, since the ITS elements appear in all of the build alternatives and therefore do not become a discriminator. Further research would be needed to determine the analytical techniques used to evaluate the effects of ITS in all of these efforts.

The next three subsections discuss the challenges and implications of including ITS in three of the key steps of the MIS process: initiation and problem definition, alternative definition, and analysis.

3.2 Initiation, Problem Definition and Measures of Effectiveness

Initiation of the MIS includes the definition of problems and needs, identifying agency participants and stakeholder groups, development of the work plan, and definition of goals, objectives, and measures of effectiveness (MOE'S). Critical to incorporating ITS elements within an MIS process is developing needs and problem statements that reflect the underlying causes of the problems within the corridor and are not geared towards traditional capacity expansion alternatives. Equally important is the need to define goals, objectives, and MOE's that are sensitive to ITS and other operational improvements for the corridor or sub-area under study. Project initiation is also where it is important to identify stakeholders and key agency participants and bring them into the MIS collaborative process. Transportation planners and operations specialists need to be brought together from the beginning to help identify the corridor issues, and how ITS can be integrated into each alternative to help address them.

The problem statement and understanding of the causes of the corridor's transportation needs can be considered, in many ways, as one of the most important factors for a successful MIS process. The problem statement helps define the range of reasonable alternatives to consider, the appropriate measures of evaluation, and even the methods and level of detail required for

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7 Examples of pioneering MIS efforts that have addressed ITS in some fashion include the Capital Beltway MIS in Northern Virginia (1995) and the IH 35 MIS in Austin Texas (1996). The I 435 study of a major river crossing in Kansas City (1996, ongoing); and the I-64 MIS in Virginia from Richmond to Virginia Beach (1997, ongoing).

analysis. It is very important that the underlying causal problems of the corridor be identified, and not simply the symptoms. For example, simply stating that the corridor's problem is "Congestion" may predispose the MIS towards infra-structure and capacity expansion alternatives. On the other hand identifying the causes of congestion as high accident locations, excessive access and egress on major arterials, and/or excessive queuing and spill over at key intersections can all point to the potential benefits ITS and other operational improvements. More important, if these are the causes of the congestion then capacity expansion may not meet the corridor's needs. Problem statements that focus solely on average (peak period) needs for capacity improvements will not lend themselves as easily to ITS solutions as those that consider the impact of incidents, variability of conditions, and operational inefficiencies in the study area.

This stage of the MIS also determines the evaluation requirements for the study, since the analysis tools and techniques must be able to estimate changes in the various measures that have been identified. Also it is the combination of measures and potential alternatives that determine what methods must be developed and used to forecast travel and other impacts for each alternative. One issue is the lack of sensitivity of the MOE's used in typical corridor studies to ITS strategies and other operational improvements that impact the reliability of service, information about the system and response to non-recurrent incidents. It is very important, therefore, to provide additional measures on the variability of the system if the impacts ITS and other strategies that focus on the operation of the system are to be analyzed in a balanced way with traditional improvements. Measures such as the standard deviation of expected arrival time, recurrent delay, incident delay, and lost opportunity time (difference between the path and mode chosen, and the best choice that could be made if information was available on all options) all can be used to capture to dimensions of a corridor's problem that ITS may help solve. Further discussion of the specific measures used in the case study is provided in Section 7.

Last, while the case study focused on development of analytic methods for MIS, equally important is the collaborative nature of MIS and the participation of both operations and planning experts. The need for bringing operations into all aspects of transportation planning is becoming recognized and has been identified as a key factor in the future national transportation policies and programs. Operations brings a different perspective to a corridor's needs, problems and potential solutions that is critical if ITS is to be fully integrated into the MIS.

3.3 Alternative Definition Issues

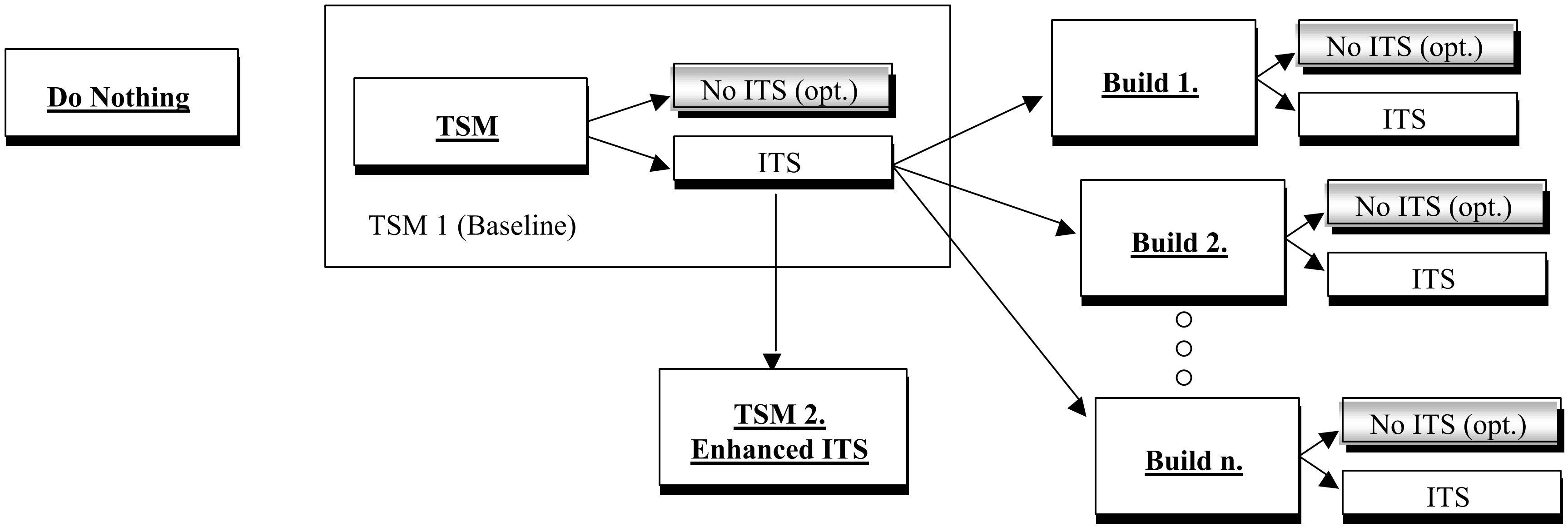
The definition of the alternatives to evaluate, and ultimately choose a preferred option from, is at the heart of the major investment study process. These include (National Transit Institute, Parsons Brinckerhoff Inc., 1996):

Do-Nothing: The Do-Nothing alternative is required by the National Environmental Policy Act (NEPA) as a baseline for estimating environmental impacts. It is defined to include those transportation facilities and services in the corridor that are likely to exist in the forecast year as well as "any improvements in other corridors that are elements of the financially constrained long range plan". All of the Do-Nothing elements must also be part of each of the other alternatives (National Transit Institute, Parsons Brinckerhoff Inc., 1996, p. 6-12). Cost effectiveness comparisons of the build alternatives with the Do-Nothing have also recently been added as part of the FTA new start criteria.

Transportation System Management: " The set of alternatives must also include a TSM alternative that represent a viable, low-cost approach to improving conditions in the corridor" (National Transit Institute, Parsons Brinckerhoff Inc., 1996, p. 6-8). The TSM alternative should represent the "best" that can realistically be done without major new physical capacity improvements. It emphasizes both small physical improvements and *operational efficiencies* such as those introduced by ITS services**.** More than one TSM alternative may be defined for a MIS analysis. All elements of the official TSM alternative, however, must also be part of the build options.

Build Options: The build options represent the reasonable major investment options for solving the MIS problem statement for the corridor which may lead to a locally preferred alternative. Each build option should be derived from the TSM alternative. "…Major new facilities are incorporated into the TSM alternative, and adjustments are made to integrate the TSM and major investment components (National Transit Institute, Parsons Brinckerhoff Inc., 1996, p. 6-15). A refined operating policy should also be developed for each build option which may include "…. ITS treatments, signalization strategies, occupancy requirements for HOV lanes, tolls, congestion pricing and reversible lanes…service frequency, integration of guideway and feeder services, fare levels, and fare structure." (National Transit Institute, Parsons Brinckerhoff Inc., 1996, p. 6-15).

ITS elements may exist in each of the above options. Where they are defined, and how, may have significant influence on the results of the analysis. As with traditional elements, ITS elements in the alternatives should develop from the Do-Nothing, to the TSM, to the build options with each level including the elements of the previous option. Figure 3-2 depicts this evolution. The systemwide characteristics of many ITS services, however, create issues on how to position ITS within a corridor study. Whether a service should be defined in the Do-Nothing, TSM, or build options also hinges on previous ITS investments and future plans in the region and the congestion management strategies found in the CMS plan (where applicable). These issues are discussed below.



ITS in Do Nothing
- Existing + Committed
- TIP
- CMS Plan

TSM 1: Base Level ITS
- Regional elements in LRP
- Expected elements in Corridors that will exist in all build options

TSM 2: Enhanced ITS
- More advanced ITS services
- High market penetration
- Private sector partnerships

ITS with Building Options
- ITS refines for each option
- Corridor ITS improvements

Figure 3-2. ITS and MIS Alternatives

One of the main characteristics of ITS services is their "system" focus and nature. The National ITS Architecture defines nine types of operation centers around which ITS services operate (Traffic Management, Transit Management, Emergency Management, etc.) These center subsystems provide management, administration, and support functions for the transportation system as a whole. The center functions are centralized and may not be limited to any corridor and their benefits dispersed. ITS services also require a communications infrastructure and system to connect the transportation network to the transportation centers. The center functions and communications system must exist, or be included in the alternatives, to implement ITS services within a corridor. There may be substantial initial and startup costs associated with implementing these center systems. Because of the initial startup costs, it is desirable to place the regional center functions (and their costs) in the Do-Nothing or Baseline TSM options.

By themselves the individual ITS strategies and elements fall into the traditional TSM definition. They are relatively low cost with respect to most capacity and service major investments. They also, by themselves, do not typically provide additional base capacity improvements of the same scale as traditional build options. However, combining several ITS strategies into an efficient and coordinated management and information system can produce more significant benefits. ITS is also developing rapidly with many ITS services just emerging as viable options.

In addition to the mandatory TSM alternative, other TSM alternatives may be defined. As shown in Figure 3-2, two TSM options may be called for when incorporating ITS in the MIS process. The first forms the baseline TSM/ITS alternative upon which the build options are developed. It includes the ITS elements that one can be reasonably certain are feasible for implementation by the horizon year, and the regional ITS elements that may be found in the approved financially constrained long range plan. ITS elements in this alternative are also included and should make logical sense with each of the build options. ITS elements that may depend upon other forces outside the public sectors control, or those that are still in development may be inappropriate for the baseline TSM.

Often, an important role of an MIS is also to provide information on what *may* occur under more optimistic than expected conditions. The Enhanced ITS TSM option can be used to give decision makers key information on the potential of ITS services to solve the corridor's problems. In the Enhanced ITS option services can be included that depend upon emerging technologies, Information Service Provider delivery of services, and/or additional commitments by actors normally outside the MIS decision process. Therefore, this alternative can show the benefits of ITS based upon the assumptions that the less certain ITS elements come to pass.

Developing ITS for each of the build options should start with the ITS elements in the baseline TSM. Each build option should then be examined and services added to maximize its operations and the goals it is trying to achieve. Thus, an advanced traffic management and coordinated signal system may not be an appropriate addition (beyond the TSM) as part of a traditional fixed guideway transit alternative since it may reduce the level of transit ridership the alternative provides. As always, the marginal costs of any services added to a build option must also be included as part of the alternative analysis.

Two other aspects of ITS services may impact the definition of the ITS elements within the alternatives. First is the issue of estimating market penetration for ITS services that depend upon the purchase of communications devices or other equipment by the individuals using them. In a traditional MIS analysis, these purchases would be internalized by an independent market demand model relating the price of the service with its use. For example, transit ridership models incorporate the fare, or user price, into the demand estimation. Market demand models for personal information and route guidance equipment, on the other hand, are not available, or are just in their development stages. Consequently, separate levels of market penetration of these services may simply need to be assumed as part of the alternative definition. The second attribute is associated with assumptions regarding the private sector provision of ITS services such as ATIS. Alternatives defined under this premise should have documented assumptions regarding public and private sector roles and cost recovery mechanisms which will factor into the analysis of alternatives.

3.4 Analysis Issues

Traditional MIS processes have focused on facility/service improvements (as seen in the definition of major investments shown in Section 2) and on average conditions and demand. ITS strategies on the other hand aim at improving: (1) operations; (2) response to non-recurrent conditions; and (3) providing better information. ITS elements and strategies have the potential to significantly enhance the alternatives and solutions of MIS efforts. However, if they are to be properly considered on an equal basis with traditional improvements, new approaches, tools, and evaluation measures must be integrated into the MIS processes to capture their contributions to the alternatives performance.

ITS strategies such as coordinated signal systems, ramp meters, automated toll readers directly impact the operation of the transportation system by reducing delays (stops), and adjusting the performance of the system as conditions change. MIS analysis efforts typically assume a steady state set of conditions over the analysis period and are consequently insensitive to changes in operations. More and more, however, it is being recognized that managing operations can offer very cost-effective mobility improvements within a corridor. MIS studies are in fact supposed to serve for the analysis of demand reduction and operational management strategies as appropriate pursuant to the CMS requirements. (Statewide Planning: Metropolitan Planning: Final Rule, FHWA & FTA, Federal Register, 10/28/93).

Non-recurrent accidents, special events, weather conditions all add up to become significant factors in the delay and congestion found in transportation systems. ITS strategies such as incident and emergency management systems, traveler information, and dynamic route guidance can help the system respond to these non-recurrent conditions. Yet, a typical MIS does not include incident occurrences in its validation of base conditions, and since its analysis is based upon average (expected) conditions, does not address the impact of incidents on the system, or an alternatives ability to respond to them.

Last, ITS strategies focus on reducing the difference between what a traveler perceives as congestion, delay, cost, etc. of the transportation network while they are traveling and the actual conditions they will see when they take their trip. Traveler information systems provide more up-to-date information on accident locations, transit routes to take, cost, etc. Route guidance systems help the system operate more efficiently by routing traffic away from accidents and other occurrences of delay. As travelers and the system operators have better, more up-to-date information significant improvements to an individual's choice can occur, especially under special circumstances. MIS studies and analysis techniques generally presume that over the long run travelers will "know" their options and make informed choices. This presumption is appropriate for an "average day" but is not representative of knowledge under highly variable conditions.

To be able to address ITS strategies, the analysis approach used in an MIS should be sensitive to the issues discussed above. The specific analysis implications of including ITS in the areas of traffic and transportation impacts, cost analysis, financial analysis, and environmental impacts are discussed below.

3.4.1 Traffic and Transportation Impacts

The discussion above provides some insight into the data and analysis needs for capturing the transportation system performance effects of ITS strategies in a combined analysis with traditional transportation alternatives. Some of the key features that are required in the analysis framework include:

- Ability to model both traditional and ITS strategies
- Incorporation of data on incidents and other factors that induce variability in traffic conditions
- Ability to model the impact of non-recurring factors on the transportation system performance
- Ability to model the state and availability of real-time surveillance information
- Ability to model traveler response to real-time information on network conditions
- Ability to model the response of the transportation system to incidents or other changes from average, expected conditions
- Ability to model the operational efficiencies of ITS improvements under average, expected conditions
- Ability to assess the combined effects of ITS services implemented together

In order to evaluate ITS and traditional alternatives as separate or combined alternatives on the same playing field, an integrated analysis approach is required. However, the evaluation tools that are best suited for estimating ITS impacts (e.g., simulation models) may not be the same as those best suited for estimating the impacts of more traditional transportation capacity or service enhancements (e.g., regional planning models). Including more than one network model in the analysis framework then raises questions of how measures should be combined across tools and the consistency and feedback requirements between the network representations for different alternatives. Because not all ITS strategies will be amenable to network modeling, and the assumptions that drive the models often rely on them, sketch analysis techniques must also be used in the analysis framework. A range of evaluation techniques is required in order to estimate the transportation and traffic impacts of each alternative.

Additional measures beyond those of typical of MIS efforts may be required in order to highlight some of the main impacts of ITS – improved trip reliability (reduced travel time variability) and reduction in non-recurring delays. The analysis approach would then have to be capable of estimating these measures for all of the alternatives under study.

3.4.2 Cost Analysis

Agencies have less experience with implementing ITS and hence have less experience on how to estimate their capital and operations and maintenance costs. Because the operations and maintenance requirements for ITS are typically higher and more uncertain than those of traditional construction projects, funding for on-going operations and maintenance is a major concern for agencies that decide to implement ITS. Life-cycle costing should be used to compare the costs of ITS alternatives with other more traditional ones.

Because some ITS strategies (such as ATIS) involve consumer purchase of equipment or services, alternatives that depend on such decisions must address these costs somewhere in the analysis. This issue is non-trivial since assumptions must be made about the costs and number of users (or market penetration). Following general MIS guidance, these costs should be treated as a user disbenefit rather than a cost, since cost is generally defined as public agency costs. In addition, since the private sector is expected to play a big role in the delivery of ATIS services, the treatment of private sector service provider costs is another issue to be addressed. One way to handle this may be through keeping the actual costs to the private sector internal to the cost analysis system by estimating user fees as the cost transfer mechanism. This in turn is a way to address the user costs.

While not unique to ITS, allocation of costs of regional systems to the corridor/sub-area is another issue to be addressed. While always function of the no-build and TSM alternative definitions, proper cost accounting is necessary to handle the use of regional support systems or the introduction of new regional services in the corridor. The fraction of regional costs allocated to the corridor must include the full cost of support systems (e.g., management centers, hardware, software, communications equipment) that are necessary to enable the service to work in the corridor. On the other hand, the allocated costs would not include costs that are accrued outside the corridor (such as equipment costs on buses that run on routes outside the corridor).

Previous MIS efforts or alternatives analyses have studied fixed guideway transit alternatives within a corridor that require the provision of central yards, shops, and control facilities. This is similar to the notion that deployment of ITS elements within a corridor depends on the existence of a central control facility that may also serve the region as a whole. These kind of parallels provide insights on how to address the ITS issues within the MIS process.

3.4.3 Financial Analysis

The financial analysis can provide a feasibility check on the ITS assumptions in the alternatives. Building on the discussion of cost analysis issues above, it is clear that the financial analysis for an MIS with significant emphasis on ITS elements can present some interesting challenges. The fact that a market analysis might need to be done as part of the study is clearly one of the challenges. Many of the issues related to public-private partnering have implications for the financial analysis and decision-making framework for the study, since many other stakeholders and decision makers (including the private sector equipment manufacturers and/or information service providers) dictate the overall viability of the defined alternative. For example, if dynamic route guidance is in an alternative, and the assumption is that it is delivered using the private sector, the viability of the alternative requires decisions on the part of the individual consumers to purchase the equipment and service, the private sector to offer the service, and likely the public sector to share traffic conditions information with the private sector. Some financial analyses might assume that the public and private sector trade data on traffic conditions, to mutual benefit, while others might assume that the information flow is more one-sided, with a potential need to include the expected value of the information into the analysis.

The typical MIS of today would not encounter all of these concerns. However, with the advent of more flexibility in the potential privatization of toll roads federally and in certain states, even more traditional MIS efforts will need to incorporate the private sector component into the financial analysis.

3.4.4 Environmental Impacts

Because ITS strategies are comprised of communications, computer, and data processing equipment, and are not as visible to the public as traditional construction alternatives, the environmental impacts of ITS are almost certainly less than those of construction alternatives, at least with respect to right-of-way, the natural environment, visual or aesthetic conditions, historic or park land resources, and social and economic impacts related to changes in access or displacement due to physical transportation system changes. In terms of air quality, the jury is still out on how ITS strategies will stack up against traditional ones, mainly because some of the relationships are not clearly understood and the state-of-the-practice analysis tools are insensitive to some characteristics of ITS (such as smoothed traffic flow) that can affect the release of emissions from vehicles.

3.5 Summary

This section has addressed some of the considerations and challenges of fully incorporating ITS into a corridor planning study process that in the past has been more suited to traditional capacity and service alternatives. The introduction of ITS strategies was discussed as part of three important stages of the MIS (or any alternatives analysis) process: the problem definition and measures of effectiveness development stage, the alternative definition stage, and the analysis stage.

This section concludes the context setting for the Seattle case study work, which is documented in the following sections.

Because the focus is on how to include and evaluate ITS as an integral element of corridor studies, some aspects of the MIS process are not addressed in detail in the case study. These include land use, environmental impacts, financial analysis, public involvement, and selection of the preferred investment strategy. Since no actual planning decision is being supported with the study, there is no need to develop or recommend a preferred investment strategy.

4. Seattle Case Study Overview

This section provides an overview of the characteristics and primary objectives of the Seattle case study and a summary of the case study approach.

4.1 Study Objectives and Characteristics

Mitretek chose the case study approach for this analysis for a number of reasons. A case study allowed us to:

1. Develop and apply analysis and evaluation techniques to a realistic metropolitan surface transportation planning problem;
2. Address and resolve the technical issues that would occur in a typical MIS study (e.g., size of the network, ITS elements, model and network conversion, level of detail required);
3. Show how ITS elements can be incorporated in a MIS (or corridor/sub-area study);
4. Show the relative contribution of ITS to MIS alternatives and impacts.

The specific objectives of the case study included:

1. Develop tools, techniques, and methodologies for incorporating ITS in the transportation planning and public sector investment processes;
2. Show the benefits and costs of using ITS to address real needs and realistic transportation problems at the corridor level;
3. Demonstrate how ITS can enhance the effectiveness of traditional "modal" alternatives;
4. Provide guidance based on the case study results that can be easily used by transportation professionals in an MIS.

Several important characteristics differentiate this case study from the typical MIS.

Because this is a federally sponsored study providing guidance for transportation planners in metropolitan regions, the specific alternatives assessed in the case study are not tied to "actual" Seattle decisions. The study had a wider scope than the actual Seattle situation and considered alternatives beyond those that might be supported in the Seattle environment. This wider scope allowed more emphasis unconstrained by any specific considerations that would affect an actual Seattle MIS for the same corridor. Consequently, the case study's methodology and lessons learned are more useful and valid than the actual quantitative results. The case study should not be read as an attempt to develop, recommend, or justify an actual investment strategy for the Seattle region.

We selected a geographic study area that provided a realistic set of conventional transportation build alternatives for the case study into which ITS elements could be integrated. The addition of ITS options affords the opportunity to assess the costs and benefits of various transportation build alternatives, with and without ITS. We chose the MIS to provide structure and context for defining and evaluating alternatives. Because the analysis is not tied to the actual planning process in Seattle, the case study can be considered a "shadow" MIS, which reflects the analysis and methodologies of an MIS without the administrative, public participation, and detailed engineering aspects of a "real" MIS process.

4.2 Study Approach

The approach is shown in Figure 4-1. A summary of each major step or task is given below. The steps are shown in sequence but, in fact, were carried out roughly in parallel.

1) **Select Region** - Both Houston and Seattle were studied in phase 1 of this project and both indicated a willingness to continue coordination with the study team. However, only one area could be chosen for phase 2 due to resource considerations. Seattle was selected as the case study area for a number of reasons:

   - the existence of a number of transportation planning model networks,
   - ability of the Seattle-area subcontractor to access Seattle-area project plans and historical data,
   - subcontractor familiarity with the Seattle-area transportation network and planning environment, and
   - the existence of good historical data on Seattle-area traffic volumes and other network statistics. These statistics are routinely collected by Washington State Department of Transportation (WSDOT) as part of its ongoing Traffic Management System efforts, and provided a good source of data for validating the models developed.

2) **Form Project Advisory Team** - Following a Federal review of the study team formation, we established a local project advisory team to provide advice to the study team. The local advisory team consists of Seattle region transportation professionals from those agencies and organizations involved in planning and operating the transportation systems in Seattle (particularly in the study corridor). The local advisory team provided their perspective on the reasonableness of the case study baseline and the definition of alternatives; as well as the evaluation approach and proposed measures of effectiveness. They also monitored the progress of the study, and reviewed the study findings and recommendations.

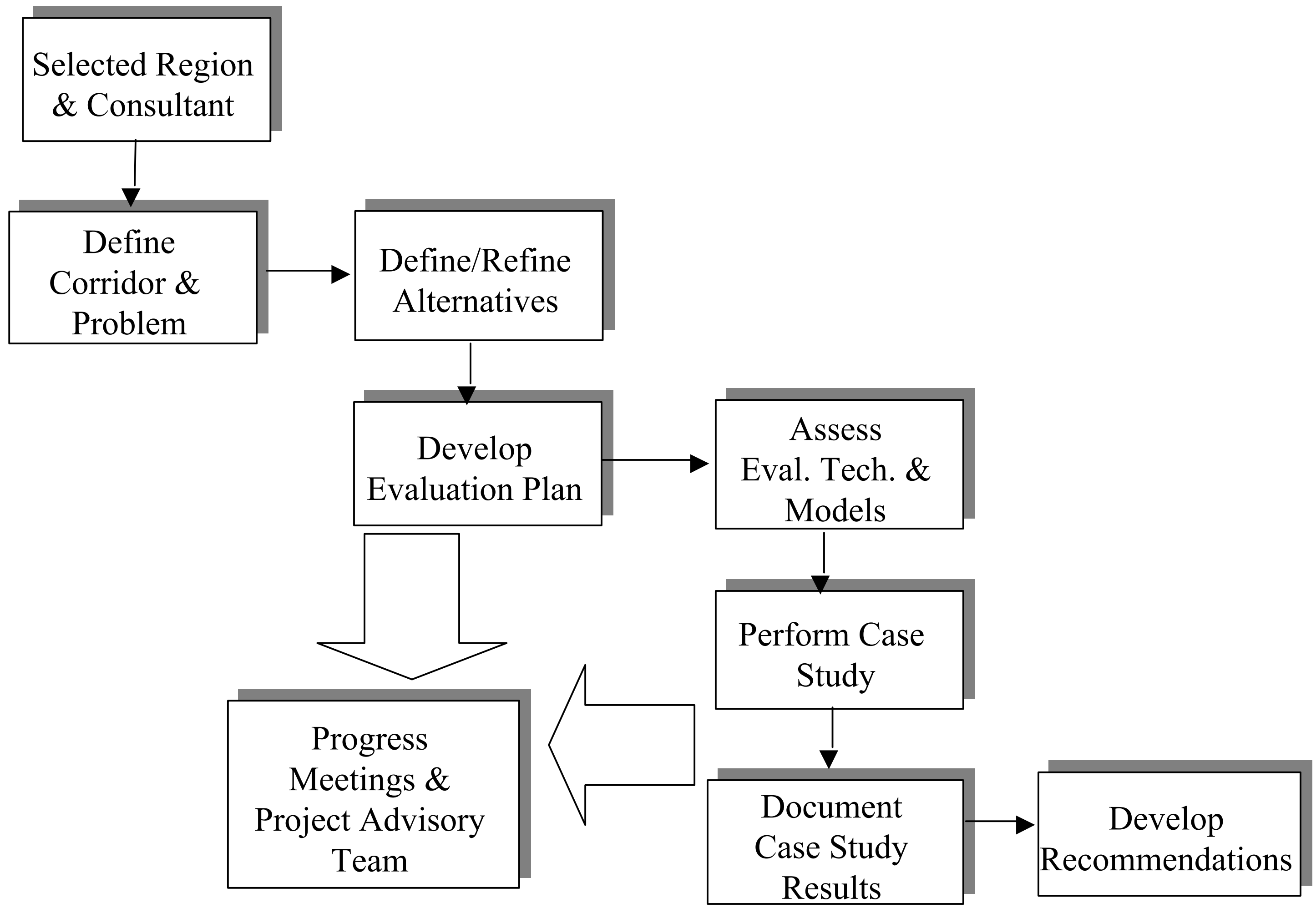


Figure 4-1. Phase 2 ITS Case Study Approach

3) The Puget Sound Regional Council (PSRC), Seattle's regional Metropolitan Planning Organization (MPO), helped to facilitate and host our meetings. Other organizations represented on the local advisory team were:

- WSDOT
- Regional Transit Authority (RTA)
- King County Metro
- King County Transportation Planning
- Community Transit
- University of Washington
- Washington State Transportation Center (TRAC)
- Local divisional offices of FHWA and FTA provided local advisory team representatives. Appendix A contains a list of the names of the individuals who served on the advisory team.

4) **Define Corridor and Problem** - Given the goals and objectives of this study, we had to select a suitable corridor with known or projected transportation needs or problems. The next section of the report (Section 5) addresses this task.

5) **Define/Refine Alternatives** - In accordance with MIS guidance, a set of distinct transportation alternatives (considered to be "build options" from the baseline network) were developed and refined as potential solutions to the transportation needs and problems in the study corridor. These alternatives represent different investment strategies and different modal orientations toward addressing the corridor transportation problems. The study objectives dictate that the alternatives specifically address the inclusion of ITS elements by themselves and in combination with more traditional build alternatives. Section 6 addresses the principles used to develop alternatives and provides a description of the baseline and the alternatives evaluated in the case study.

6) **Develop Evaluation Approach** - In this study, "analysis" refers to processes that develop information on the costs, benefits, and impacts of alternative transportation projects. Transportation models, for example, might provide such information on impacts, while financial analyses might provide information on costs. Analysis makes no normative judgments, i.e., makes no attempt to place values on the information. In contrast, "evaluation" refers to processes that use such information to make comparisons, such as to make clear the advantages and disadvantages of the alternatives in addressing transportation needs and problems. For example, use of measures of effectiveness require judgments about the values of what is effective and how to measure it. Evaluation puts the analysis-generated information into a framework that facilitates decisions among the transportation alternatives. By "evaluation approach," we mean the combination of both analysis and evaluation processes. An analysis approach was developed and used to estimate the costs and transportation impacts of each alternative. In order to achieve the study objectives, the evaluation approach included analysis methods and evaluation tools which had to capture the impacts of ITS alternatives as well as of the traditional transportation alternatives. The analysis methods and evaluation measures are discussed in Section 7. The evaluation of the alternatives is covered in Section 9.

7) **Assess Analysis Methods** - Part of the development of the analysis methods involved research on the available analysis techniques and transportation models that were both well-documented and could meet the study objectives. We reviewed a variety of analysis methods, i.e., networks, simulations, and sketch planning techniques that could address ITS strategies. This task resulted in the final set of transportation models and evaluation methods for the case study that are documented in section 7.

8) **Perform case study** - This step involves the actual execution of the evaluation approach to analysis of possible transportation alternatives for the Seattle metropolitan corridor.

9) **Document Case Study Results** - The results of the model validation process are reported in Section 8. The results of the alternatives evaluation can be found in Section 9.

10) **Develop Recommendations** - Based on the results and their implications and the experiences/ lessons learned during the case study, the project team made several recommendations regarding analytical issues and next steps. These recommendations are captured in Section 10.

5. Selection of Study Corridor

5.1 Selection of Study Corridor

After selecting the Seattle region for the case study, the study team developed a list of factors to select a corridor of study in the Seattle area. Overall stipulations for selection of a candidate corridor included:

- have “generalizable” transportation attributes,
- allow realistic application of a variety of ITS strategies, and
- have transportation data readily available to expedite the case study.

The corridor candidates were evaluated on the following selection factors:

1. Geographical extent
2. Transportation planning and operating jurisdictions
3. Traffic volumes
4. Type and condition of major transportation facilities
5. Service levels
6. Origin-destination (OD) patterns and land use
7. Topography
8. Potential changes in transportation facilities
9. Current or future transportation problems
10. Existence of a freeway with alternative routes (for traffic diversions)
11. Existing and potential multi-modal options
12. Data availability

The Seattle metropolitan region is topographically confined, with Puget Sound to the West and Lake Washington to the East of the Seattle central business district (CBD). South of the Seattle CBD, the region includes multiple activity concentrations, including the city of Tacoma, the Fort Lewis Military Reservation, the Seattle Tacoma International Airport, and the Port of Seattle. To the East of the Seattle CBD and Lake Washington are the Bellevue area and Redmond (home of software giant Microsoft), and to the North is the city of Everett (home of the Boeing aircraft assembly plant). Since all of these areas are on a relatively narrow north-south axis, the initial candidate corridors could be grouped easily into three categories:

1. Segments of Interstate Route 5 (I-5), the main North-South freeway through the Seattle CBD;

2. Interstate Route 405 (I-405), a hemi-beltway through Bellevue and the Seattle environs on the East side of Lake Washington, intersecting I-5 North and South of the Seattle CBD; and

3. The East-West State Route 520 (SR 520) and Interstate Route 90 (I-90), which bridge Lake Washington, connecting the Seattle CBD with Bellevue to the East.

The I-90 corridor extending East from Seattle across Lake Washington and Mercer Island to Bellevue was considered, but eliminated since it did not have alternative routings for diversions of traffic off the freeway, except for the routes named above, and it would not be a candidate for multi-modal operations.

Considering the three main interstate routes in the region, five corridors, two with subparts, were defined:

1. The North Corridor - centered on I-5 Northward from the Seattle CBD to about Everett
2. The Tacoma CBD - centered on I-5
3. The South Corridor -
    a) Centered on I-5 Southward from the Seattle CBD
    b) Centered on SR 509.
4. The Bridge Crossing
    a) Centered on I-90.
    b) Centered on SR 520.
5. The Eastern Circumferential - centered on the I-405 hemi-beltway.

All five corridors include limited access routes, as well as less controlled routes providing diversions from the primary limited access route. The subparts of corridor 3 allow a focus on a freeway or on an arterial facility. The subparts of corridor 4 are both limited access and alternatives for the other. The attributes of the subparts of corridors 3 and 4 are sufficiently different to deserve separate listings. The resulting seven corridors were used initially to develop detailed attributes, according to the twelve selection factors, for further discussion with the local advisory team. Table 5-1 shows an initial assessment of the twelve selection factors against the seven potential corridors.

Table 5-1. Corridor Selection Characteristics (multiple pages)

	CORR. 1	CORR. 2	CORRIDOR 3		CORRIDOR 4		CORR. 5
	I-5 North	I-5: Tacoma	I-5 South	SR 509	I-90	SR 520	I-405
Geographical Extent	Seattle CBD to 164th St, Sno Co.	SR 512 to Pierce /King Co. Line	Pierce/King Co. Line to Seattle CBD	188th St to 1st Ave S Bridge	Issaquah to Seattle CBD	Redmond to I-5	I-5 (Tukwila) to I-5 (Sno Co)
Jurisdictions	WSDOT; PSRC King Co. (Incl. Metro); Snohomish Co.; Cities: Seattle, Lynnwood, Mountlake Terrace; Comm. Transit	WSDOT, PSRC, Peirce Co., City of Tacoma, Pierce Transit Port of Tacoma	WSDOT; PSRC King Co. (Incl. Metro); Cities Seattle Federal Way; Pierce Transit	WSDOT; PSRC King Co. (Incl. Metro); Cities Seattle, Burien, Sea Trac	WSDOT; PSRC King Co. (Incl. Metro); Cities Seattle Issaquah, Bellevue, Mercer Island	WSDOT; PSRC King Co. (Incl. Metro); Cities Seattle Redmond, Bellevue, Kirkland	WSDOT; PSRC King Co. (Incl. Metro); Cities Bellevue, Tukwila, Renton, Kirkland, Botbell, Lynnwood, Comm. Transit
Selected Volumes							
ADT	114200	91500	94400	22700	65000	54000	81000
AM Pk Hr	7900	6600	8700	2500	6300	3800	6400
PM Pk Hr	8300	5700	9000	3000	5600	3800	6000
Express (SB/NB)	5520/5375						
Type/Condition	3-5 lane freeway with 2-4 lane reversible roadway, directional split toward Seattle CBD, relatively high transit service. HOV lanes in most of corridor	3-5 lane freeway, low directional split, low to moderate transit service. HOV lanes planned throughout corridor	3-5 lane freeway significant directional split toward Seattle CBD, relatively high transit service. HOV lanes built/committed throughout corridor	3-4 lane freeway, moderate dir. split toward Seattle, low transit service. HOV lanes planned for 1st Ave S Bridge HOV bypass NB onto bridge	3-5 lane fwy. With 2-lane reversible roadway across Mercer Is. & bridges, dir. split toward Seattle CBD, relatively high transit service. HOV lanes in most of corridor	2-3 lane fwy., dir split toward Seattle CBD, very high transit service over bridge. HOV planned on part of corridor (politically sensitive corridor	2-4 lane circumferential fwy. low dir. Split, minimal transit service. Outside HOV lanes built/committed in most of corridor (inside HOV through Tukwila)

Table 5-1. Corridor Selection Characteristics (multiple pages)

	CORR. 1	CORR. 2	CORRIDOR 3		CORRIDOR 4		CORR. 5
	I-5 North	**I-5: Tacoma**	**I-5 South**	**SR 509**	**I-90**	**SR 520**	**I-405**
Service Levels	Heavy peak period congestion. Significantly exacerbated by incidents	Existing congestion primarily due to incidents. Future regular peak period congestion forecasted	Heavy peak period congestion. Significantly exacerbated by incidents	Peak period congestion limited to 1st Ave S bridge, which is currently being expanded.	Low congestion east of I-405 (spillover to I-405). Moderate peak period congestion West of I-405. Significantly exacerbated by incidents	Heavy peak period congestion. Significantly exacerbated by incidents	Heavy peak period congestion. Significantly exacerbated by incidents
OD Patterns/Land Use	Suburban to urban freeway. Heavy commute trip orientation to/from Seattle CBD. Land use built out along much of corridor.	Urban Freeway. Multiple intra-, inter-, and through corridor trips, Room for land use growth at south end of corridor.	Suburban to urban freeway. Heavy commute trip orientation to/from Seattle CBD. Limited land use growth potential.	Suburban freeway. Links airport, suburbs, industrial areas w/Seattle. Minimal growth potential as-is (unless later linked with I-5).	Suburban to urban freeway. Heavy commute trip orientation to/from Seattle CBD. Experiencing more growth than other corridors- heavy recreational demand.	Suburban to urban freeway. Heavy commute trip orientation to/from Seattle CBD. Potential for growth at east end of corridor.	Suburban circumferential freeway. Widely dispersed trip patterns. Land use relatively low density.
Topography	Level to moderate terrain	Level to moderate terrain	Level to moderate terrain		Level to moderate terrain		Level to moderate terrain
Potential Changes	Light rail parallel to portion of corridor	Commuter rail parallel to corridor	Commuter rail parallel to corridor		Light rail parallel to portion of corridor	HOV lanes up to bridge	HOV lanes to move to the inside

Table 5-1. Corridor Selection Characteristics (multiple pages)

	CORR. 1	CORR. 2	CORRIDOR 3		CORRIDOR 4		CORR. 5
	I-5 North	I-5: Tacoma	I-5 South	SR 509	I-90	SR 520	I-405
Current or Future Problems	Significant existing congestion and safety problems	Significant existing safety problems. Flow near capacity. Future congestion.	Significant existing congestion and safety problems	Congestion on 1st Avenue South Bridge. Connection to I-5 will increase congestion.	Moderate existing congestion and safety problems.	Significant existing congestion and safety problems west of I-405.	Significant existing congestion and safety problems
Limited Access plus Alternative Routes?	Yes	Yes	Yes	Yes	Yes	Yes	Limited alt. routes
Existing or Potential Multi Modal Options?	Currently significant bus transit and car/vanpool usage. Future rail potential.	Currently heavily SOV. Potential for commuter rail, increased bus and carpool.	Currently significant bus transit and car/vanpool usage. Future rail potential.		Currently significant bus transit and car/vanpool usage. Future rail potential in part of corridor.	Heaviest bus transit in region. Moderate car/vanpool use. (Avg. veh. occ. is 1.77 in AM peak.)	Heavily SOV with limited transit/carpooling. Some potential for increased bus transit.
Data Availability	Real time surveillance, volume & speed from loops, CCTV. Existing volumes, vehicle occupancies, accident data, transit data, signal system, land use and network model data.	Existing volumes, vehicle occupancies, accident data, transit data, signal system, land use and network model data.	Limited real time surveillance, existing volumes, vehicle occupancies, accident data, transit data, signal system, land use and network model data.		Real time surveillance, existing volumes, vehicle occupancies, accident data, transit data, signal system, land use and network model data.	Real time surveillance, existing volumes, vehicle occupancies, accident data, transit data, signal system, land use and network model data.	Limited real time surveillance, existing volumes, vehicle occupancies, accident data, transit data, signal system, land use and network model data.

In addition to the twelve corridor selection characteristics, several other analysis considerations were used to differentiate potential corridors. These considerations included the availability and status of network models, previous or ongoing planning studies, and the applicability of prior case study work to these locations.

For the final selection of a corridor, the seven corridors were recombined into five candidates. Examining the attributes of the five, just four factors strongly differentiated the choices. These are:

1. Model Readiness: availability of subarea network models.
2. Data Availability (Baseline and Validation): especially good historical traffic flow data from permanent loop detectors and other surveillance systems.
3. Range of Alternatives (including alternate routes): existence of a mix of conditions and modes providing wide latitude for applying ITS technologies.
4. Transferability: the degree to which the corridor resembles other metropolitan areas.

Each corridor was given a rating of favorable, neutral or less favorable on this reduced set of selection factors. These results are shown in Table 5-2.

As shown, the candidate corridors varied little on the model readiness factor. There were scattered subarea models for all the candidate corridors. The corridor with the most favorable ratings was Corridor 1, the North Corridor (centered on I-5 north). The telling factor for this corridor was the operation of the North Seattle Traffic Management Center. This represented an intensive and historical database of permanent loop detector information, as well an ongoing surveillance and control capability. In terms of alternative routes, SR 99 parallels I-5 in this area up to Everett, and SR 99 itself provided interesting options for arterial treatments.

The corridor also contained light rail and commuter rail proposals from the Regional Transit Authority (RTA) referendum, that passed a few months after our corridor selection. The North section of I-5 contains an express section and HOV lanes, with extensive ramp metering. All factors considered, Corridor 1 was the dominant choice for our case study purposes.

5.1.1 The Study Corridor

Evaluating these key factors, the North Corridor was selected for our case study analysis. This corridor is described further in Subsection 5.1.2. Figure 5-1 shows the North Corridor's relation to the other corridors in the Seattle region. Figure 5-2 depicts the North Corridor geography in more detail.

Table 5-2. Corridor Evaluation Matrix

Selection Criteria	CORRIDOR North Corridor	CORRIDOR Tacoma CBD	CORRIDOR South Corridor	CORRIDOR Bridge Crossing	CORRIDOR Eastern Circ. I-405
1. Model Readiness	O	O	O	O	O
2. Data Availability (Baseline and Validation)	+	O	O	O	O
3. Alternatives Applicability(incl. Alt. Routes)	+	+	+		
4. Transferability	+	O	+		

KEY

+ = Favorable **o** = Neutral = Unfavorable

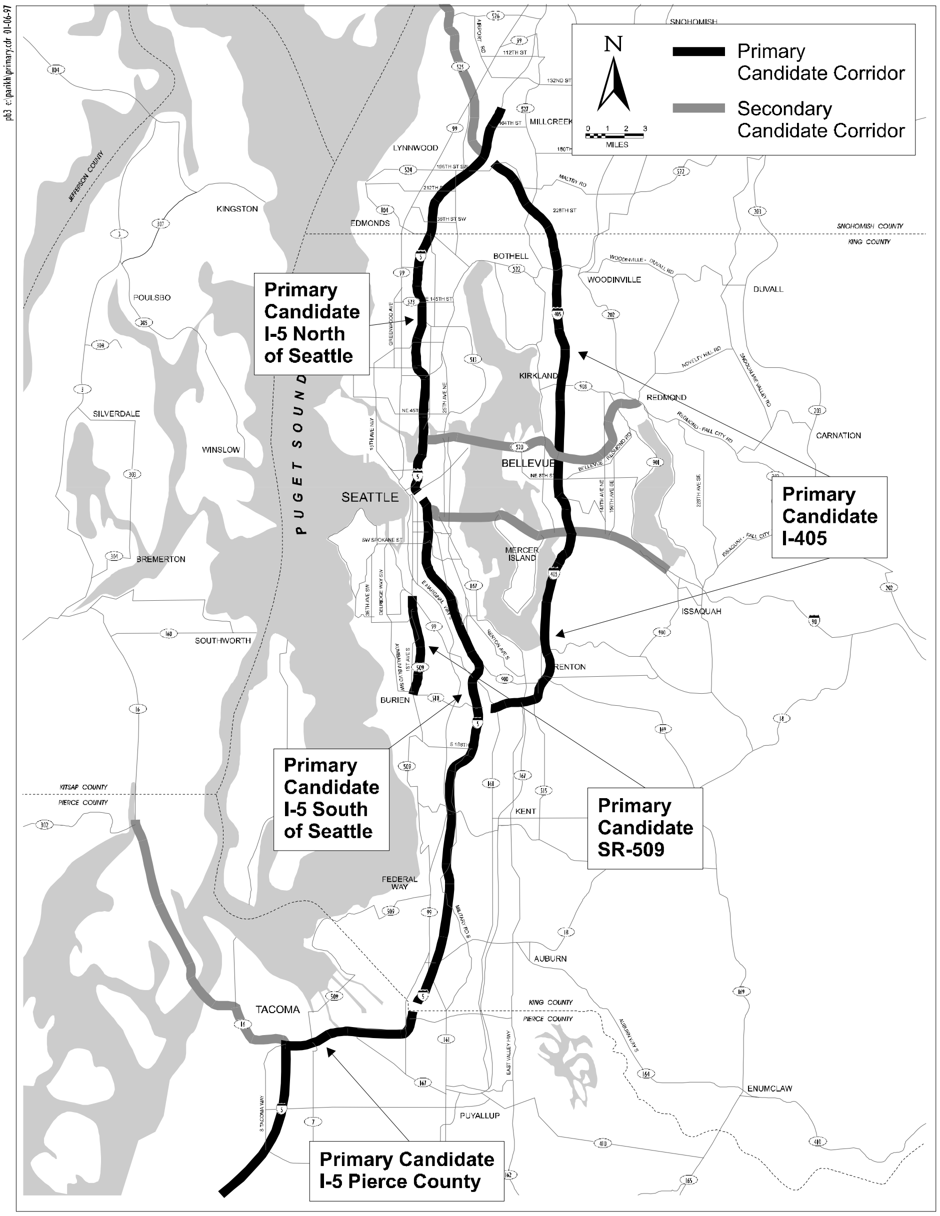


Figure 5-1. The North Corridor in Regional Context

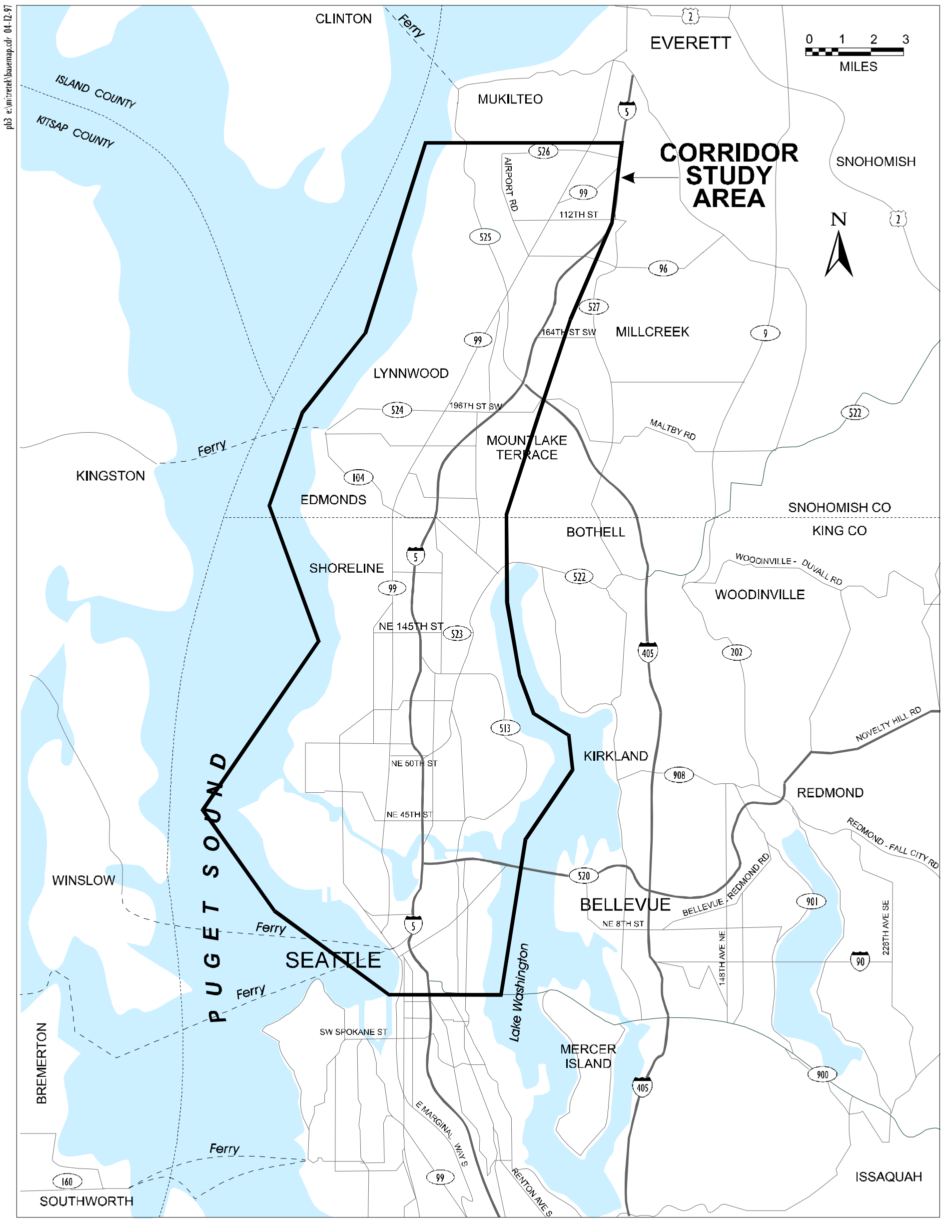


Figure 5-2. The Detailed Analysis Area for the North Corridor

5.1.2 Description

The North Corridor contains the two primary continuous north-south routes into the Seattle CBD---I-5 and SR 99. The dominant traffic flow direction is associated with commuting to and from the Seattle CBD and the areas immediately south, however, these two routes also carry the significant contra-flow traffic to Boeing-Everett and other points north of the Seattle CBD. These routes provide the only two limited access highways of the six routes crossing the Ship Canal, the waterway that bisects Seattle west of Lake Washington. The Seattle CBD can also be approached from the northeast via SR 522 (Lake City Way) around the top of Lake Washington. Some of this traffic filters down through the University district, but most of this northeast flow will also join I-5 at the junction (Exchange 171) that tends to be the AM peak choke point, north of the Ship Canal crossing. The east-west crossing on SR 520 across Lake Washington feeds primarily into I-5 (Exchange 168). Traffic on I-405 going around the CBD through Bellevue and Redmond to the east of Lake Washington largely joins I-5 (at Exchanges 182 in the north and 154 in the south).

The Ship Canal connects Lake Washington to Puget Sound and cuts off northern Seattle from the CBD. The I-5 bridge and the SR 99 (Aurora) bridge are the two major crossings, along with four local crossings. SR 99 is a limited access facility through the CBD and across the Aurora Bridge. I-5 operates separate, and reversible, express lanes from the CBD, across the Ship Canal which re-merge north of the bridge. The traffic patterns, in particular during the morning commute, tend to show that the I-5 bridge crossing is not the major bottleneck, but that the significant flow constraint is the interaction of express lane, HOV crossovers and ramp traffic near Northgate (Exchange 173), just to the north of the I-5 bridge.

After selecting the North Corridor, we left open the issue of the corridor termini. For emulation of an MIS, a part of the corridor close to the CBD, with both transit and highway segments, would suffice. As discussed in Section 7, the analysis was conducted on both a subarea and on a regional scale. We used a regional planning-scale model for the northern part of the region, and a more detailed traffic simulation model for a subarea closer to the CBD. Constraints of the traffic simulation model confined the corridor to the subarea from North of the CBD to the junction of I-5 and I-405. The case study corridor was analyzed at the two scale levels, generally along I-5 from the CBD toward Everett, and extending east to the planned North-South line of the light rail transit system.Seattle voters approved a Regional Transit Authority (RTA) plan for light rail service from the CBD and across the Ship Canal through the University District. In addition, express bus service will extend around the top of Lake Washington, along I-5 and SR 99. Commuter rail will extend near the shore of Puget Sound, north to Everett. Along with existing bus transit service and HOV facilities on I-5, the selected case study corridor is multi-modal.

The entire signalized street network in the corridor, along with the freeways already under TMC control, will be coordinated jointly between WSDOT and the local jurisdictions through the TMC. This coordination will extend to more of the corridor the surveillance and control capabilities that are now limited to the freeways under WSDOT control. The coordination also will provide greater latitude for operational solutions to traffic congestion, especially due to incidents, or to other unusual conditions in the corridor.

5.2 Problem Statement

The I-5 North Corridor becomes a bottleneck to mobility for Seattle's topographically constrained regional travel. Significant highway capacity increases through construction are unlikely in the densely developed areas extending north from the CBD and across the Ship Canal. The diversity of modes and facility types in the study corridor promotes the idea of using ITS operational approaches.

In keeping with an MIS approach, a general problem statement is formulated to guide the identification of alternatives, including ITS, and the measures of effectiveness for the case study. The problem statement for the I-5 North Corridor is:

"Develop and evaluate alternatives to reduce congestion and improve mobility along the North Corridor extending from the Seattle CBD north to SR 526."

6. Alternatives Considered

Given the selected corridor and the transportation problem statement discussed in the previous section, the next task was to identify a number of different alternative transportation solutions or strategies (referred to as alternatives) that could address the problem. This section provides insight into the alternative development and screening process (Sections 6.1 and 6.2) and then defines the alternatives studied in the case study (Section 6.3). Each of the prescribed alternatives is then evaluated according to the analysis approach (or analysis plan) described in Section 7. Thus, the development of alternatives is crucial to the overall study process and is the first major window for demonstrating how to include ITS elements.

6.1 Principles for Alternative Development

The study team generally followed MIS guidance (National Transit Institute, Parsons Brinckerhoff Inc., 1996) for development of the transportation alternatives to be evaluated. The guiding principles for alternative development used in the case study can be summarized as follows:

- Include Do-Nothing (No Build) as an explicitly considered alternative (including existing infrastructure/services and committed projects)
- Consider a wide range of transportation options/ solutions (different modes, ITS, etc.)
- Consider only "reasonable" alternatives that have the potential to address the transportation needs and problems
- Ensure that each alternative is distinct from the others
- Refine each alternative to optimize its capabilities
- Keep the number of alternatives manageable
- Ensure that the alternatives address the study goals and objectives (that is, that they demonstrate ITS-only options, traditional "build" improvements, and alternatives that are combinations of traditional and ITS elements)
- Keep the ITS elements relatively consistent in the build alternatives with ITS, while tailoring the ITS strategies to the specific characteristics of the build, in order to obtain some comparison of the relative performance of a common ITS "investment package" across different alternatives

The last two bullets in the above list of guiding principles are quite specific to this study and are not necessarily meant to be turned into guidance on how ITS should be included in these types of studies. For example, keeping a consistent set of ITS elements across any alternative with ITS is somewhat constraining and may be at cross purposes with the particular policy objectives of a given build alternative. A more flexible approach would be to change the ITS strategies or elements in a way that would be consistent with the emphasis of a particular alternative (for example, if the alternative emphasizes transit relative to SOV capacity, then the ITS elements to be combined with that particular alternative would be only those that are consistent with the transit emphasis). For the purposes of this study, the experimental design advantages of keeping a relatively consistent package of ITS elements outweighed the advantages of highlighting the more flexible approach. Although not highlighted in the study, one of the experimental design advantages is that a common package of ITS elements could actually be thought of as a separate (very aggressive) TSM alternative, upon which the conventional build alternatives are added.

In order to investigate important technical issues and to simplify the analysis, some MIS guidelines were not rigidly followed. For example, in order to demonstrate the analysis approach for Transit Signal Priority and to provide a cleaner comparison, it was not assumed to be in the Baseline Alternative, even though Seattle has committed to using this ITS strategy along a few bus routes in or near the study corridor. Another simplification that was made early in the study was to combine the Do-Nothing conceptual alternative with the traditional "lower cost" Transportation System Management (TSM) or Travel Demand Management (TDM) alternatives. This simplification did not compromise the objectives or applicability of the study and allowed more time and resources to be spent on development of the build alternatives and analysis approach.

The level of detail that the alternatives had to be taken to corresponds to the level needed for performing cost estimation and modeling/evaluation of transportation impacts. The level of specification needed to do programming level cost estimation was usually the driving force in the final level of detail prescribed. The alternatives design concept, scope, basic configuration parameters, and high-level equipment requirements were generally specified. Preliminary engineering-type design options such as exact alignment options or the use of standards are not addressed by the study alternatives, since the intent was to stay at the level needed for evaluation of transportation impacts[8].

6.2 Development and Initial Screening of Alternatives

A wide variety of alternatives were initially considered by the study team, resulting in the following set of conceptual alternatives, which will be elaborated upon in the remainder of this section:

8 More detailed engineering, financial and environmental assessments would be carried out in a typical MIS to support detailed design and detailed design and environmental analysis

1. **Do-Nothing/TSM** - a baseline case (the baseline is characterized by traditional transportation facilities and services as well as programmed ITS elements). All other alternatives are constructed from this baseline.
2. **ITS Rich** - an alternative comprised only of ITS strategies added to the Do-Nothing/TSM
3. **SOV Capacity Expansion** - a traditional type of alternative emphasizing roadway upgrades and increased general purpose capacity
4. **SOV Capacity Expansion Plus ITS** - an alternative that combines ITS strategies with the third alternative
5. **HOV/Busway** - another traditional type of alternative emphasizing HOV and transit options for addressing the North Corridor's transportation needs
6. **HOV/Busway Plus ITS** - an alternative that combines ITS strategies with the fifth alternative
7. **Toll Facility/ Pricing** - an alternative that would introduce toll collection on the I-5 reversible express lanes as a way of working the demand side of the problem
8. **Toll Facility/ Pricing Plus ITS** - an alternative that combines ITS strategies with the seventh alternative
9. **Fixed Guideway Transit** - an alternative that focuses on fixed guideway rail service to serve the transportation needs of the North Corridor
10. **Fixed Guideway Transit Plus ITS** - an alternative that combines ITS strategies with the ninth alternative

6.2.1 Overview of Conceptual Alternatives

An overview description of each conceptual build alternative (except for the combined traditional plus ITS alternatives) is provided below to better illustrate the nature of the preliminary set of alternatives (the ITS elements will be discussed in more detail later in Section 6.3):

6.2.1.1 ITS Rich Alternative

The ITS Rich Alternative is intended to show how far the addition of ITS strategies (beyond Baseline) without any traditional build components could go towards improving the transportation conditions in the North Corridor. An aggressive implementation of ITS strategies in the North Corridor is assumed, composed of traffic management and surveillance, incident and emergency management strategies, ITS services for transit, and traveler information improvements.

6.2.1.2 SOV Capacity Expansion Alternative

Currently, SR 99 parallels I-5 and is both an undivided arterial and a limited access freeway. From SR 599 to SR 509 in the south, SR 99 is a limited access freeway. It then becomes an arterial to just before Spokane Street where it then reverts back to a limited access freeway as it passes through downtown Seattle. At N 50th Street near the Woodland Park Zoo, it becomes an arterial once again and continues as such until it connects with I-5 near Mukilteo.

Under this alternative, the portion of SR 99 north of N 50th Street would be turned into an expressway. This would involve limiting access to and from SR 99 by placing median barriers to eliminate turns onto and off of SR 99. This limited access highway could extend to the King/Snohomish County Line or as far north as traffic volumes warrant it. Some suggested access points are: N 85th Street, Northgate Way, N 130th Avenue, N 145th Street, 175th Street, and 196th Street SW.

In addition, SR 525 (in the northern portion of the study corridor) would be widened between SR 99 and I-5.

6.2.1.3 Busway/HOV Alternative

Under this alternative, the I-5 freeway would have continuous, barrier-separated, high occupancy vehicle (HOV) lanes from downtown Seattle to SR 526 in South Everett by the year 2020. To achieve this, a movable barrier-separated southbound contraflow HOV lane would be added on the express lanes during the PM peak from Ravenna Boulevard to Stewart Street as proposed in the Puget Sound HOV Pre-Design Studies. A series of additional HOV improvements would be implemented such as putting HOV lanes on SR 526 (Airport Rd to I-5) and SR 99 (Winona Ave. N. to CBD), implementing arterial HOV on SR 99 (Winona Ave. N to Everett Mall Way), and construction of various freeway to freeway HOV connectors and direct access ramps.

Transit improvements for this alternative would include completion of a transit lane on SR 522, addition of several new regional express bus routes with frequent service, and construction of several park-and-ride lots.

6.2.1.4 Toll Facility/Pricing Alternative

Under this alternative, the reversible express lanes that extend from downtown Seattle to Northgate would become a toll road. Transit and HOVs would be allowed to use these lanes at either no cost or a reduced cost. This would allow non-SOV vehicles to benefit by using an uncongested highway that would provide adequate speed and reliability. If there is enough capacity, SOVs could pay a toll and be allowed to use these lanes. By allowing SOVs to buy into this roadway, funds could be generated to ensure the maintenance of the facility; however, the tolls for SOVs would have to be set such that a significantly higher level of service is maintained on the toll road relative to the I-5 mainline. Tolls could be based on the amount of congestion as well as by time of the day.

Tolls on other roads in the I-5/North Corridor could be considered as part of this alternative; however, a significant amount of construction would be required in order to provide the control needed to implement them.

6.2.1.5 Fixed Guideway Transit Alternative

This alternative would be based on the Regional Transit Authority's proposal which was voted in during the November 1996 election. The light rail plan includes twenty-five miles of a starter system with twenty-six stations within walking distance of major destinations as well as connections to local and regional bus service. The line would run from the SeaTac Airport to the University District connecting Rainier Valley, downtown Seattle, First Hill, and Capitol Hill. If additional funding can be secured, the line would be extended to Northgate through Roosevelt. In downtown Seattle, the existing bus tunnel would be turned share both bus and light-rail use. The northern portion of the light-rail system from downtown Seattle to the University District would have nine stations. The segment between downtown Seattle and the University District would be via a tunnel.

In addition to the light rail, commuter rail service would be in place offering two-way, rush-hour train service using existing railroad tracks between Everett, Seattle, Tacoma and Lakewood. The eighty-one mile commuter rail system would include fourteen stations. In the North Corridor, service between Seattle and Everett would have five stations in Seattle, Edmonds, Mukilteo, Bond Street Station in Everett, and Everett Station. (Stations may also be added at Richmond Beach and Ballard if added funding is secured; however, they will not be assumed for this analysis.)

Implementation of commuter rail would require making track and signal improvements, improving the capacity of those lines for other passenger and freight trains as well. Park-and-ride lots, transit centers and stations would also be constructed to support the commuter rail system.

6.2.2 Alternative Screening Process

Due the nature of the study, a formal evaluation and screening process was not followed in narrowing down the list of alternatives to further develop and analyze. The study team decided to drop four of the nine "build" alternatives due to schedule and resource limitations. In coordination with the Seattle Project Advisory Team, the decision was made to drop alternatives 7-10 in the above list (Toll Facility/Pricing, Toll Facility/Pricing Plus ITS, Fixed Guideway Transit, and Fixed Guideway Transit Plus ITS). Several factors led to the decision regarding the particular alternatives that were dropped. Once the decision was made to drop a conventional build alternative, eliminating the same alternative with additional ITS elements was a foregone conclusion.

The Toll/Facility Pricing alternative was considered to be less generalizable than the other traditional alternatives and also less likely to be viable given the history and geometric characteristics of the I-5 Expressway. Another consideration was that an example policy analysis on the topic of transportation pricing was recently completed for the Seattle area (ECO Northwest and Deakin Harvey Skabardonis, 1994). One important finding of the pricing investigation was that substantial public opposition is likely to be encountered with the introduction of many of the potential pricing strategies described in the alternative overview. The previous effort provides a base of information on pricing options and their analysis, and it was felt further investigation was not warranted. Lastly, because of the empirical evidence already documented (Mitretek Systems, October 1997), there did not appear to be much interest in developing techniques to evaluate the effectiveness of ITS strategies such as electronic toll collection systems (which are quite complementary to this particular alternative). Some of the congestion-based aspects of the alternative would have been difficult to implement without the use of electronic toll collection. Indeed, almost every new toll system implemented across the U.S. within the last few years uses some type of electronic toll collection method.

The Fixed Guideway Transit alternative was dropped for a variety of reasons, but mostly due to resource and schedule considerations given that significant network model coding work would be required in order to evaluate it. Another important reason why the alternative was not taken any further is that the HOV/Busway Plus ITS alternative covers nearly all of the potential ITS strategies that can be combined with the Fixed Guideway Transit alternative; thus, the potential gain in methodology development experience for incorporating ITS elements would have been relatively small.

The remaining five alternatives were further developed and evaluated. Figure 6-1 illustrates the alternatives development philosophy used in the case study. The shaded boxes (above the horizontal dashed line) indicate the final set of alternatives taken into the development, refinement, and evaluation stages. The dashed lines originating from the ITS Rich box indicate the commonality of the ITS elements across all build alternatives with ITS. The next subsection provides more details on the final set of alternatives for the case study, including more discussion of how ITS was included with the alternatives.

6.3 Description of Final Alternatives

The final set of alternatives for the case study are detailed and depicted in this subsection. In the interest of highlighting the incorporation of ITS strategies in the alternatives, more detail is provided on the specifics of the ITS strategies. The Horizon Year for the alternatives analysis is 2020. Because of its importance in setting the stage for the analysis, the baseline alternative is described first, with particular attention to the ITS elements assumed to be present.

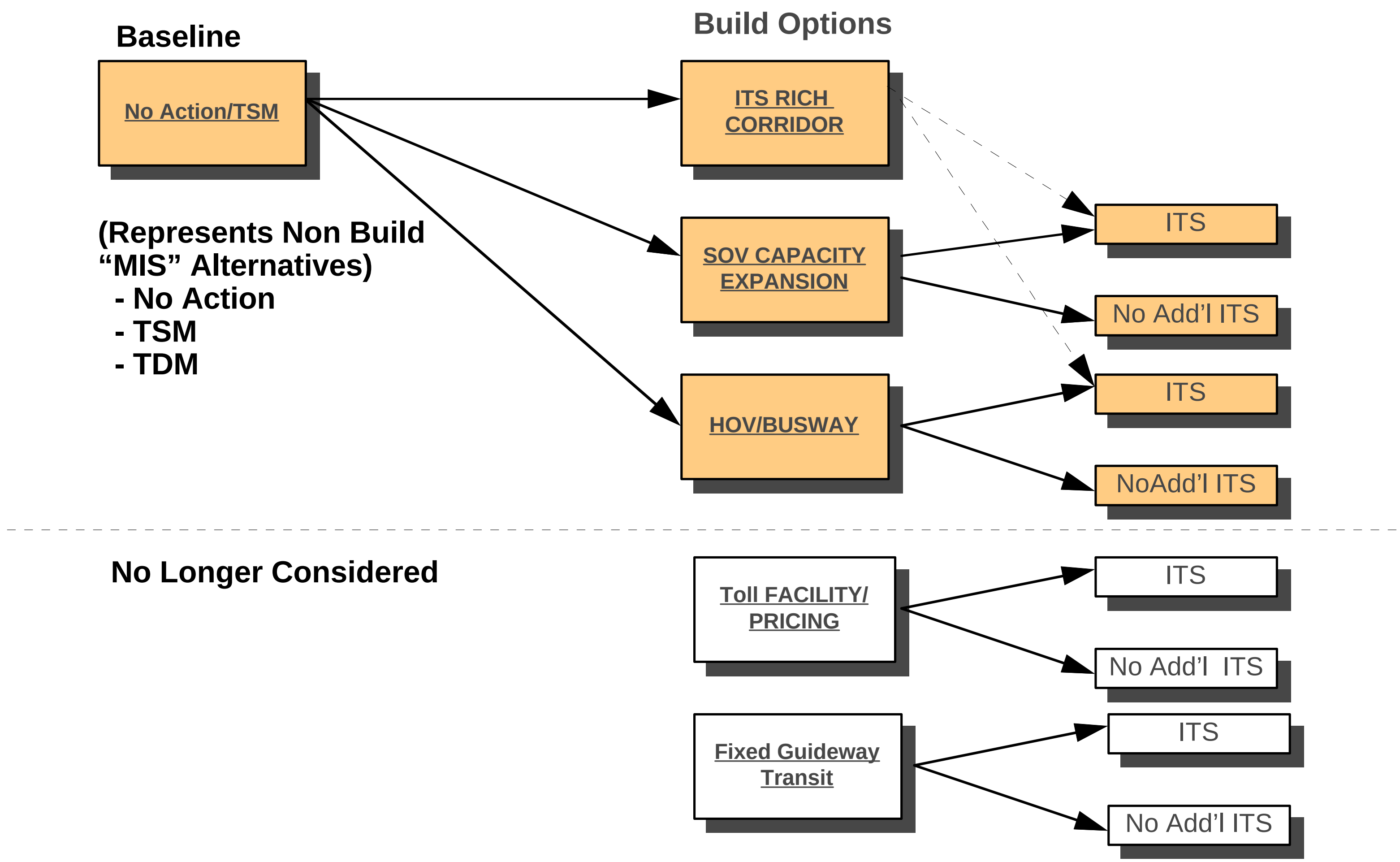


Figure 6-1. Alternatives Development Approach for Seattle ITS Case Study

6.3.1 Do-Nothing/TSM Baseline

Following MIS Guidance, the Do-Nothing/TSM Baseline (often referred to as the Baseline) alternative represents the current transportation systems, infrastructure, and services and the projects that have been committed to (financially and otherwise) in the current TIP. In this case study, the 1996-1998 TIP of the PSRC was used to define the region's committed projects, which corresponds to the PSRC 2020 No-Build Network. The North Corridor characteristics were covered in Section 5 and will not be repeated here. Instead, the major traditional committed projects and TSM elements beyond the existing infrastructure and the ITS elements assumed to be represented in the Baseline alternative are described.

The PSRC 2020 No-Build Network, which was used as the basis for this alternative, includes all committed projects within the regional modeling area (inside and outside of the North Corridor). A separate TSM alternative was not constructed; however, these type of strategies are assumed to be represented in the 2020 No-Build Network. The following bullets are indicative of traditional projects that are currently committed or being built in the North Corridor study area:

- HOV lanes added between 128th St. SE and SR 526
- 196th St. SW interchange upgrade
- Various arterial street improvements (also reflects TSM)

TSM elements assumed to be in the Baseline include the following examples (some of which are contained in the 1995 MTP for the Seattle region):

- Intersection modifications and management (channelization, widening, exclusive turn lanes)
- TDM measures such as ridesharing, and flexible/alternate work schedules (these are not explicitly addressed in this case study)
- Various transit service improvements throughout the region

Table 6-1 defines the ITS infrastructure and services assumed to be in the Baseline for this study. The major ITS categories included in the table are Traffic Management/ Surveillance, Incident and Emergency Management Systems, Advanced Public Transportation Systems (APTS), and Advanced Traveler Information Systems (ATIS). The table provides a short description of each ITS element in the Baseline and an indication of the level of deployment assumed in the study corridor. In some cases, assumptions that are crucial to the cost estimation of the other (build) alternatives are documented in the last column. While the ITS elements in the table largely represent the actual Seattle situation and near term committed plans (including plans based on the Model Deployment Initiative Program), no attempt was made to exactly represent the current and committed projects, and some liberties were taken

Table 6-1. Do-Nothing/TSM Baseline ITS Elements (multiple pages)

ITS Elements	*Description*	*Assumed Level of Deployment*	*Cost Considerations*
Traffic Management/ Surveillance Baseline (e.g., ATMS)			
Signal Systems	Existing time-of-day signal system with traffic responsive elements (minimal ramp metering and arterial control coordination) --system supports emergency signal priority at some	Arterials/ streets throughout the North Corridor	.
Traffic Management System	WSDOT surveillance (FLOW) system with communications system, vehicle detectors, cameras, ramp meters, (VMS and HAR installations covered in ATIS)	Existing/Committed North Corridor Coverage mainly on I-5 from below CBD to just north of SR 525. Regional coverage includes I-405, I-90, SR 520.	Build off existing TMS system
.	.	Ramp meters at various locations on I-5 throughout North Corridor	.
.	.	Good surveillance (1/2 mile spacing) coverage on freeways only - spotty coverage elsewhere	.
Transportation Management Centers (TMCs)	Existing/committed TMCs and operations/control centers (WSDOT TSMC, King County Metro operations/dispatch center, local signal system operations	Good coverage of North Corridor	Assume that no brand new physical plants/ facilities are necessary to implement ITS strategies in build alternatives
Communications Systems/ Infrastructure	North Seattle ATMS Project assumed to be completed providing infrastructure/ techniques for traffic data sharing and coordination of operations for traffic management systems of 15 jurisdictions in North	Full North Corridor coverage	Assume that this comm. system supports most ITS needs (infrastructure side)

Table 6-1. Do-Nothing/TSM Baseline ITS Elements (multiple pages)

ITS Elements	***Description***	***Assumed Level of Deployment***	***Cost Considerations***
Incident and Emergency Management Baseline			
Incident Management Sytems	All current/committed programs	Region-wide coverage (10 incident response vehicles)	
Emergency Traffic Signal Priority	Allows emergency/fire/medical vehicle to gain priority at selected signals throughout the network for quicker response	Region-wide coverage	
APTS (Transit) Baseline			
Transit Management System	Sign-post based transit vehicle tracking (AVL), GIS and CAD system with 2-way communications for schedule adherence monitoring, coordination, and security purposes	King County Metro Transit - region/fleet wide	
Regional Rideshare Program	Links employees with carpools, vanpools, and customized bus services	Serves customers in 8-county region	
Electronic Fare Payment System	Regionally integrated fare card (smartcard) system for customer convenience and operator cost savings + enables flexible pricing	Regional (Metro Transit, Community Transit, Pierce Transit, and Washington State Ferries (WSF))	
Trip planning/ customer assistance	All programs designed to support customers needs for schedule and route information (automated and manual) e.g., Interactive Voice Response phone system, BUS-TIME, BusView, Regional Automated Trip	Regional - Metro Transit assumed to have most advanced system	
Support systems	Scheduling, operator assignment, passenger counting system, electronic fare boxes,	Regional	

Table 6-1. Do-Nothing/TSM Baseline ITS Elements (multiple pages)

ITS Elements	*Description*	*Assumed Level of Deployment*	*Cost Considerations*
ATIS Baseline			
Advisory-based Traveler Information			
	Public display devices		
	VMS signs	Coverage on freeways/ along baseline TMS at strategic locations	
	Information kiosks/displays	A few at strategic transit center locations in the North Corridor	
	Broadcast systems		
	Radio traffic reports	Area wide	
	FM Subcarrier Systems (SWIFT, MDI)	Area wide	
	HAR sites	At strategic locations - run by WSDOT as part of TMS	
	Other - cellular phone information system, etc.	Area wide	
Multimodal Pre-Trip Planning			
	Public Access Internet (Similar to current FLOW map), telephone information, Cable TV distribution, etc.	5% market penetration of travelers - area wide coverage (baseline surveillance system)	Assume that the customers use equipment bought for other purposes (e.g., PCs, TVs, phones)
			No service charge for the traffic information (free)

with the assumptions (as discussed in Section 6.1). For more information, the Seattle Application for Participation in the ITS Model Deployment Initiative Program (1996) provides additional details on actual existing and planned ITS infrastructure and services in the area.

The Advanced Traffic Management infrastructure included in the Baseline includes WSDOT Traffic Management System elements along I-5 and other major freeways such as ramp meters, surveillance (cameras and vehicle detectors), communications system. As denoted, good coverage (e.g., 1/2 mile spacing of loops) exists mainly on the freeways. Several transportation management or operations centers already exist to serve the North Corridor; the study team assumed that these centers would be capable of implementing the ITS strategies in the build alternatives (eliminating the need for construction of brand new centers). The signal system in the Baseline can be described as a time-of-day system with traffic responsive elements such as actuation in some areas. The North Seattle ATMS Project is assumed to be completed providing the communications infrastructure and techniques for sharing of traffic-related data and coordination of operations for traffic management systems of 15 jurisdictions in North Corridor. This project is important to the Baseline since it provides full North Corridor coverage and connects the transportation management systems in nine cities, two counties, three transit agencies, and WSDOT together with a communications infrastructure which can be leveraged in the build alternatives.

The Incident and Emergency Management Systems assumed in the Baseline basically consists of existing and committed programs. In the Seattle area, WSDOT has ten incident response vehicles that are in radio contact with WSDOT and Washington State Police. Information on the incidents is relayed to FLOW system operators for distribution to the media and the public. Emergency vehicles can gain priority at selected traffic signals in the region.

Several ITS-related elements relevant to the study are included in the Baseline under the APTS category, including transit management systems, rideshare programs, electronic fare payment, trip planning/customer assistance, and other supporting systems. These types of transit applications have already been implemented in Seattle. Many of them are being upgraded as part of the Model Deployment Initiative Program in Seattle (which can be considered to be committed for the purposes of this study). As stated earlier, no transit priority system is assumed to be in the Baseline alternative.

For ATIS, the Baseline assumptions roughly correspond to actual conditions. Advisory-based traveler information (based largely on reports of incidents, severe congestion, and major transit service disruptions) is considered to be widespread and includes (1) public display devices such as Variable Message Signs (VMS) and information kiosks, (2) broadcast systems such as radio traffic reports, FM subcarrier systems such as being tested with a small number of users in Seattle, and Highway Advisory Radio (HAR), and (3) other systems such as the cellular phone traffic information service. Free, publicly available multi-modal pre-trip planning information is assumed to be available via the Internet (similar to the current FLOW map), telephone information, and cable TV distribution. Approximately 5% of travelers are assumed (for analysis purposes) to use this information to help plan their travel. Travelers are assumed to use equipment bought for other purposes to gain access to this pre-trip information (such as a computer or telephone).

It should be reiterated that all other build alternatives consist of changes or additions to the Baseline alternative. This applies to ITS elements as well as the traditional transportation elements.

6.3.2 ITS Rich Alternative

The ITS Rich Alternative is intended to show how far the addition of ITS strategies (beyond Baseline) without any traditional build components could go towards improving the transportation conditions in the North Corridor. An aggressive implementation of ITS strategies in the North Corridor is assumed, for two primary reasons. First, this assumption allows an assessment of how the costs and impacts of this alternative measure up against the more traditional alternatives. Second, it provides the study team the opportunity to demonstrate the evaluation methods that can be applied to a variety of ITS strategies. Figures 6-2, 6-3, and 6-4 depict the key ATMS and APTS strategies included in the ITS Rich Alternative. Table 6-2 provides a description of each element in the ITS Rich alternative and an indication of the level of deployment assumed in the study corridor. Assumptions that are crucial to the cost estimation are documented in the last two columns.

The ATMS improvements in the ITS Rich alternative include a signal system upgrade throughout the key arterial routes in the North Corridor. This advanced coordinated/ adaptive signal system is assumed to be based on the use of traffic responsive elements, cross-jurisdictional coordination, integrated ramp metering and arterial control, use of emerging signal control algorithms in the research community, and use of standards for compatibility. Figure 6-2 shows the primary and secondary corridors of the advanced signal system that assumed to be used for the AM peak period (which is the period of time being modeled, as discussed in Section 7). The primary corridors, which are assumed to be favored over secondary corridors for receiving green-wave priority in the signal optimization, correspond to the key north-south routes providing significant capacity during the AM peak. Because of the variety of travel patterns south of 130th Street and north of the ship channel, a network control grid operation is assumed to be in place at the intersections in this area (which includes the University District). More about these assumptions and their implications for the analysis is discussed in Section 7.

Also included as an ATMS improvement is an expansion of the traffic management system surveillance and communications infrastructure along the major freeways and state routes in the northern part of the study corridor. Figure 6-3 portrays these extensions to the Baseline along I-5, SR 526, and SR 525. These extensions will allow better freeway management and improved incident management detection, verification, and response capabilities. In addition, the quality and quantity of real-time traffic data for ATIS is improved.

Incident and Emergency Management Systems tend to be regional in nature and are hard to confine to the North Corridor. The associated improvements assumed in the ITS Rich Alternative are:

(1) A fleet tracking and management system, with Dynamic Route Guidance capabilities added to the 10 (Baseline) incident response vehicles, to enable faster response to incidents

(2) Mayday Support Systems that allow GPS-based information on incident location and other critical information to be transmitted to and received by the incident response dispatch center

The assumption for the Mayday Support Systems is that the public sector costs only include the communications equipment and software needed to capture this type of information.

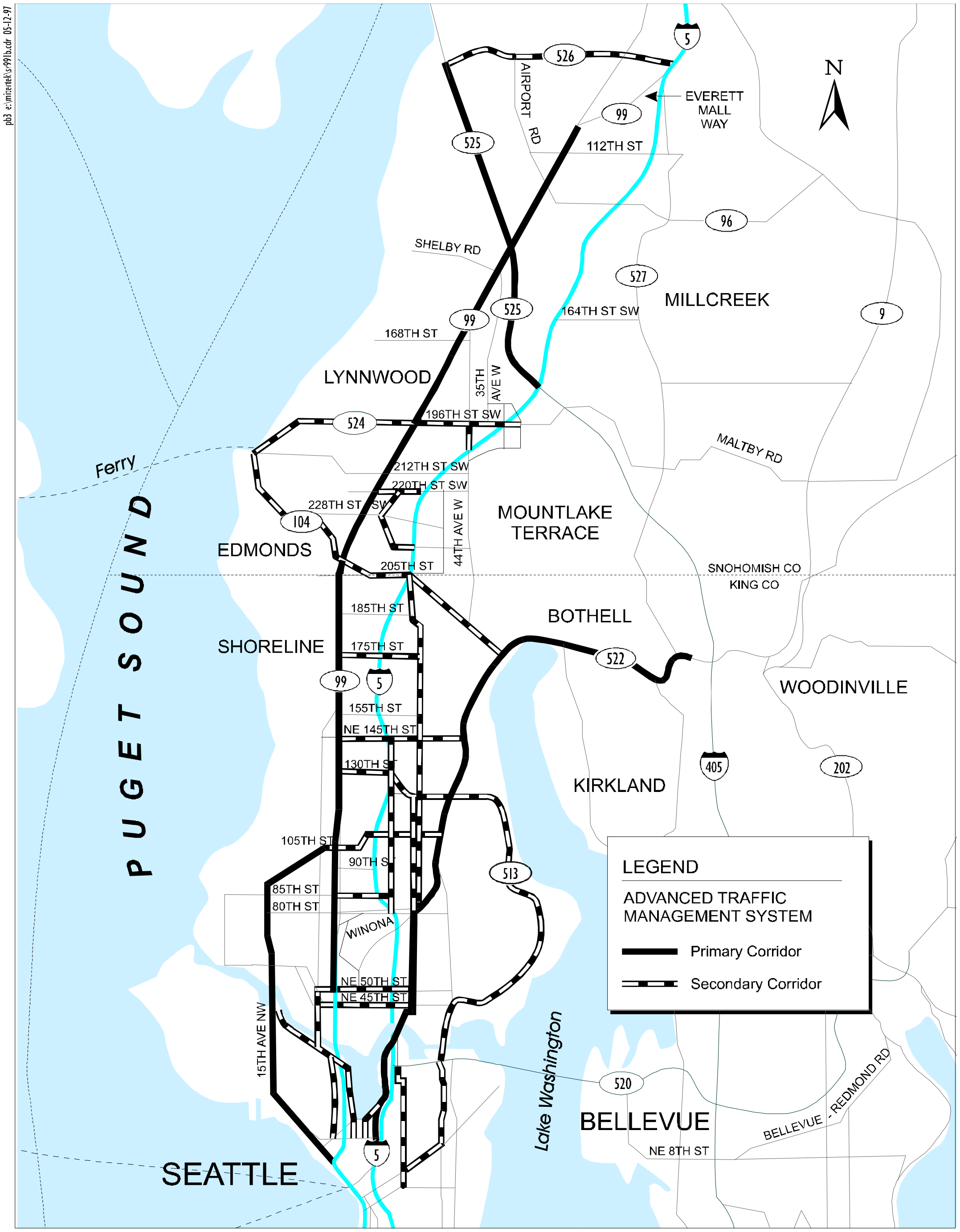


Figure 6-2. ITS Rich Alternative ATMS Plan (Part A)

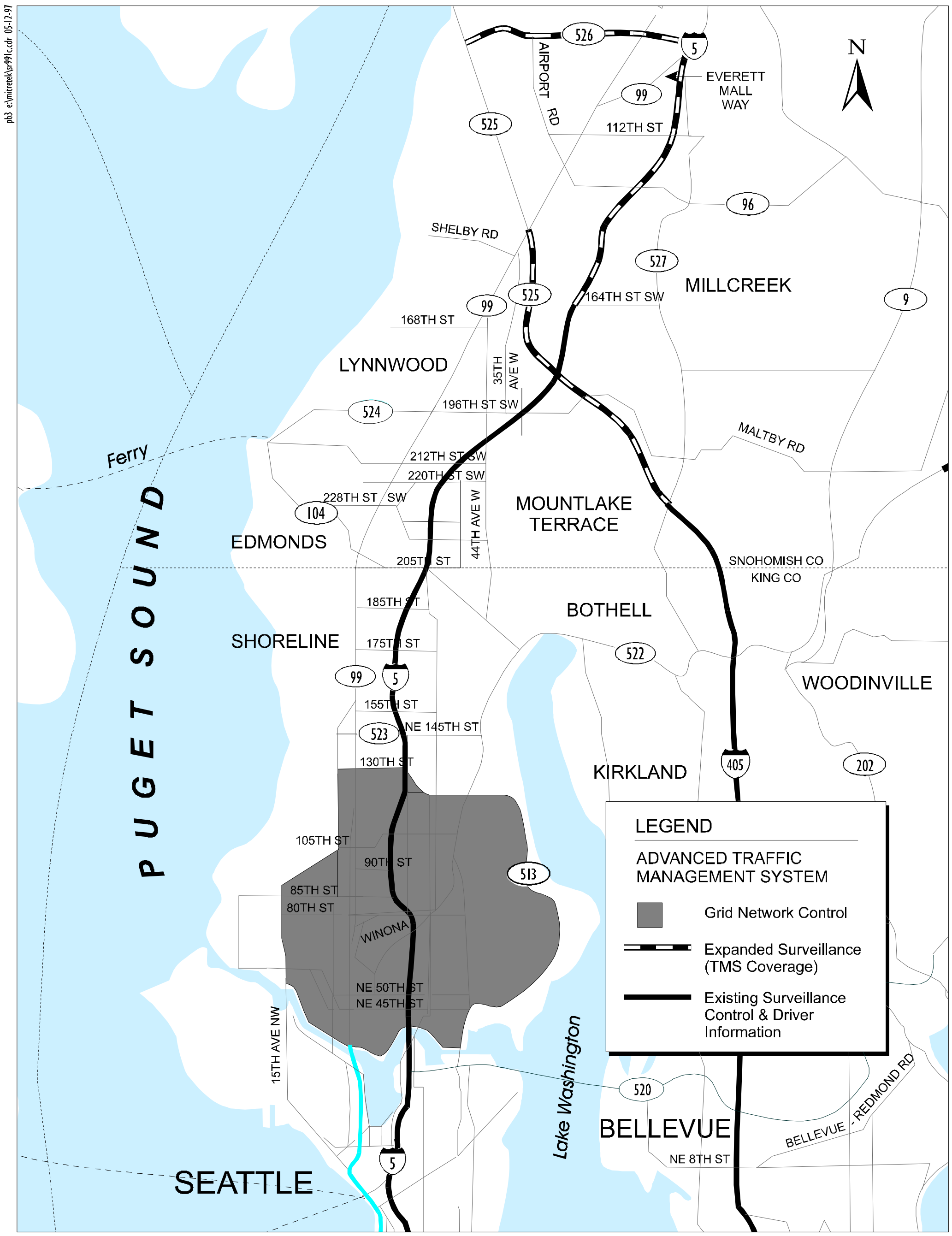


Figure 6-3. ITS Rich Alternative ATMS Plan (Part B)

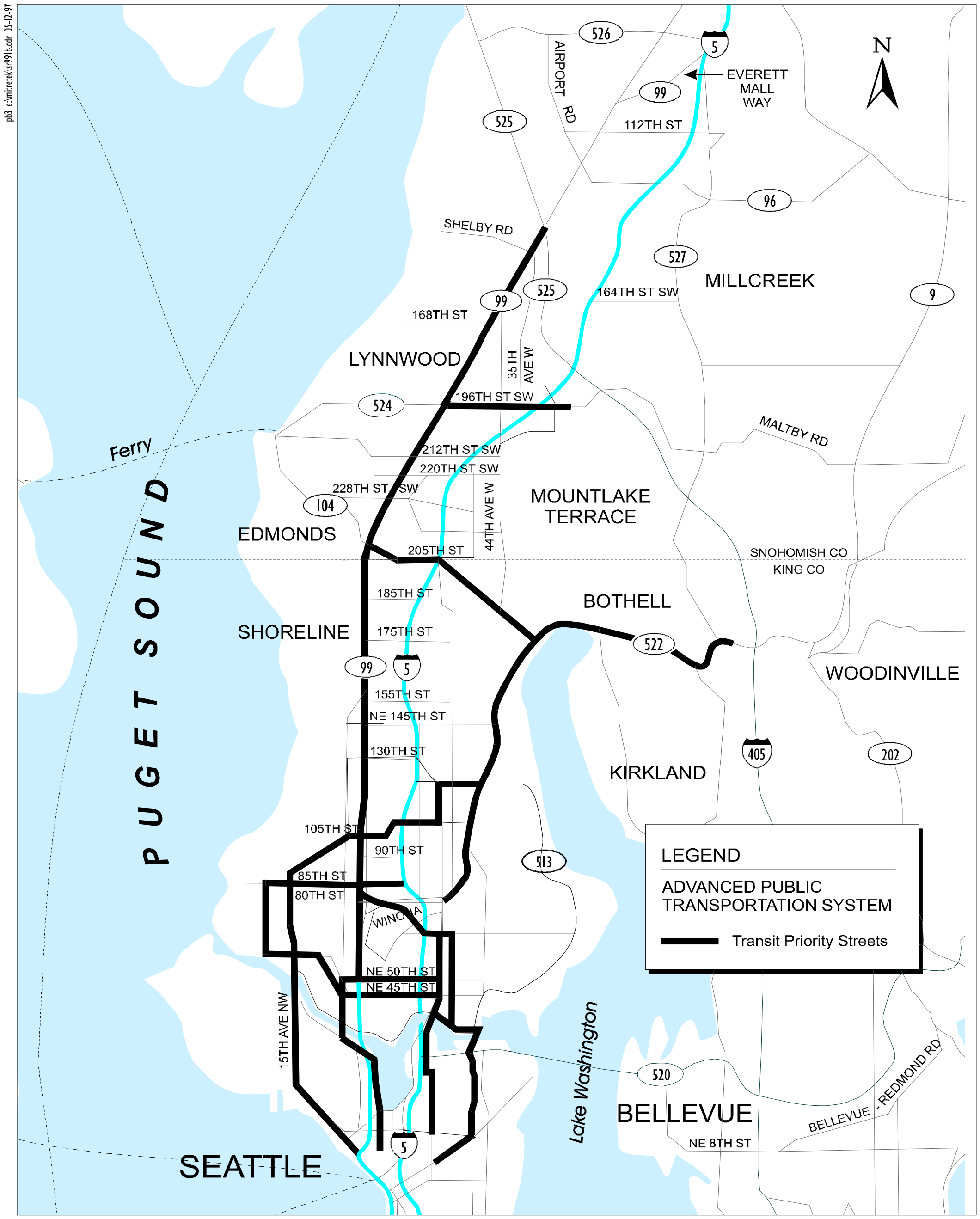


Figure 6-4. ITS Rich Alternative Transit Priority Plan

Table 6-2. ITS Rich Alternative Improvements (multiple pages)

ITS Elements	*Description*	*Assumed Level of Deployment*	*Capital Cost Assumptions and Elements*	*O&M cost considerations*
Traffic Management/ Surveillance Improvements (e.g., ATMS)				
Coordinated/Adaptive Signal System	Replace signal system along major routes in the corridor with advanced traffic responsive system with good ramp metering and arterial control coordination --system also supports the transit/EMS priority system plan	See ATMS Plan for Primary Corridor, Secondary Corridor, and Grid Control Areas	Cost to upgrade system at central locations and at the intersections corresponding to ATMS Plan with some additional local surveillance to drive responsive control algorithms - same unit cost applies to all upgraded	includes change in communications, operations, maintenance costs associated with the new system
Expanded Traffic Management System	WSDOT surveillance system with communications system, vehicle detectors, cameras, ramp meters, (VMS and HAR installations covered in ATIS)	Expanded Coverage on I-5, SR 526, SR 525, SR 104 (See ATMS Plan for limits) Corresponds to Future TMS Expansion Plan	Use typical configuration, loop detectors every 1/2 mile, CCTV cameras at major interchanges, one new ramp metering installation(s) at SR 526	consider operator costs (labor), maintenance, etc. (includes VMS/ HAR O&M)
			Communications System to handle expanded TMS	
			TSMC upgrade cost for computers, software, communications, data processing, and physical facility	

Table 6-2. ITS Rich Alternative Improvements (multiple pages)

ITS Elements	*Description*	*Assumed Level of Deployment*	*Capital Cost Assumptions and Elements*	*O&M cost considerations*
Incident and Emergency Management Improvements				
Incident Response Team Fleet tracking, management and Dynamic Route Guidance System	Use tracking system and route guidance to provide faster response to incidents	Region-wide implementation (all vehicles in baseline fleet - currently 10) -- scale to North Corridor estimate	For baseline vehicles in fleet, include same in-vehicle equipment as Dynamic Route Guidance (GPS, map database, communications transceiver, processor, GUI/display) + some central costs for tracking system/	includes communications costs plus other O&M
Mayday Support	Allows GPS information on incident locations and type/severity of situation to be received by the dispatch center. This information could be sent from private Mayday service provider or Route Guidance ISP based on their customers assistance requests.	Region-wide (scale to North Corridor estimate)	Communications/ software/ GIS integration costs at the dispatch center	

ITS Elements	*Description*	*Assumed Level of Deployment*	*Capital Cost Assumptions and Elements*	*O&M cost considerations*
APTS Improvements				
Transit Priority System	AVI (transponder)-based communications between transit vehicle and roadside (signal) controller allows green phase adjustments (primarily extensions) to enhance transit service	See transit priority plan - several routes within the North Corridor	Transit vehicles must be equipped with transponder units; wireless readers at priority intersections (assume signals upgraded by ATMS plan are capable of handling this system); central computing/ software for transit probe data analysis	communications system costs are mostly maintenance (no usage fee)
Enhanced/Expanded Transit Management System	GPS-based transit vehicle tracking, GIS, and CAD system with 2-way communications for schedule adherence monitoring, feeder coordination, and security purposes	Region-wide (scale to North Corridor estimate)	Transit vehicle equipment costs include GPS, comm. transceiver, GUI/data terminal, and display; central costs include software upgrade - assume same wireless communications system is used as baseline	for central and vehicle systems

Table 6-2. ITS Rich Alternative Improvements (multiple pages)

ITS Elements	*Description*	*Assumed Level of Deployment*	*Capital Cost Assumptions and Elements*	*O&M cost considerations*
ATIS Improvements				
Advisory-based Traveler Information				
Information is primarily exception-based. Coverage includes freeways, major state routes, and transit service disruptions				
	Public display devices			
	VMS signs	Coverage on freeways/ major state routes in primary corridor plan at strategic locations prior to diversion points	Add 15 VMS signs beyond baseline to coincide w/ expanded TMS coverage (surveillance) in ATMS plan and a few along ATMS primary corridor routes (e.g., SR 99, SR	Communications infrastucture O&M is covered by TMS and/or Baseline
	Information kiosks/displays	At strategic transit centers/ Park & Ride locations in the corridor	Add 10 Information kiosks/displays at Transit centers/ key Park & Ride lots in corridor	
	Broadcast systems			
	Radio traffic reports	area wide	none beyond baseline	none beyond baseline
	HAR sites	At strategic locations - run by WSDOT as part of TMS	Add one HAR site near I-5/ SR 99/ SR 526	Incremental costs negligible compared to overall TMS O&M costs
	Public Access Internet	Coverage on freeways/ major state routes area wide	none beyond baseline	none beyond baseline
			No special traveler/vehicle equipment is needed beyond radio or computer (no cost beyond baseline)	No traveler O&M costs

Table 6-2. ITS Rich Alternative Improvements (multiple pages)

ITS Elements	*Description*	*Assumed Level of Deployment*	*Capital Cost Assumptions and Elements*	*O&M cost considerations*
Multimodal Personalized Pre-Trip Planning				
Information is personalized, based on knowledge of network conditions, with rich coverage on both transit and roadways				
	Advanced, interactive fixed-end (home, office based) trip planning service (provided by private Information Service Provider - ISP)	10% market penetration of travelers	None beyond baseline -- assume that the customers use equipment bought for other purposes (e.g., PCs,	$10/month service fee for customers assumed to handle total cost transfer
Dynamic Route Guidance				
Information is based on knowledge of network (roadway only) conditions, drivers assumed to provide real-time probe reports				
	Drivers in vehicles equipped with this service are provided real-time route updates during their trip through the network based on current traffic conditions	10% market penetration of SOV and HOV (carpool) travelers	In-vehicle equipment costs include GPS, map database, communications transceiver, processor, GUI, and display	$10/month service fee for customers assumed to handle cost transfer for ISP
	Real-time updates provided by private ISP			$5 monthly marginal fee for all communications

Table 6-2. ITS Rich Alternative Improvements (multiple pages)

The private sector is assumed to be providing the Mayday service, and those costs (including in-vehicle costs) are not included in the ITS Rich Alternative.

APTS improvements under this alternative include an aggressive transit priority system implementation and an enhanced transit management system. Figure 6-4 depicts the transit priority routes for the ITS Rich Alternative. All of the streets outfitted with transit priority equipment are also upgraded signals under the ATMS plan (many of them fall along the primary corridors such as SR 522, SR 99, and 15th Ave. NW. The transit vehicles are equipped with a transponder tag (identification tag) in order to be detected as they approach the equipped intersections. Depending on the traffic conditions and state of the signal, a decision can then be made to extend the green phase (or provide an early green phase) in order to allow the bus to clear the intersection. There are a variety of operational strategies that can be employed, some of which would only be activated if the bus is behind schedule. However, an important point to remember is that no traditional infrastructure improvements such as transit-only or HOV lanes, widened lanes, bus turnout bays, special transit bypasses, or other similar improvements beyond the Baseline are assumed to be provided in the ITS Rich Alternative. This may limit the effectiveness of the transit priority system, since the bus traffic typically shares lanes with other vehicles and may not be able to get to the front of the intersection queue in order to obtain the benefits of the priority scheme.

The other APTS improvement assumed for the ITS Rich Alternative is an enhanced/ expanded transit tracking and management system. A GPS-based system with two-way data and voice communications between buses and the dispatch/operations center provides the ability to track and communicate with the buses at any location and any time within the coverage area, and is useful for security reasons as well as operational reasons. The system is assumed to provide a wealth of information on schedule delays and estimated arrival times for ATIS users. Because a two-way communications system exists for the King County Metro fleet in the Baseline, it is assumed to carry over to this alternative.

Many of the ITS applications relevant to transit are regional in nature. Transit priority, which is highlighted in this analysis, is the obvious exception. Because many transit-related ITS applications are already included in the Baseline alternative, there was no need to include them under ITS Rich.

The ATIS services assumed in the ITS Rich Alternative include enhanced advisory-based traveler information, multimodal personalized pre-trip planning, and dynamic route guidance. The level of deployment and market penetration, assumptions on the information availability, and cost assumptions and elements are discussed in Table 6-2. The deployment assumptions made are that the private sector offers the advanced ATIS user services to consumers, and a certain level of market penetration is exogenously assumed (the assumption is that the services have been offered for a while and the market penetration corresponds to a steady-state value). Though the method of data sharing is not critical to our analysis, the public and private sectors are assumed to share traffic data, so that full set of information on network conditions and transit services are available to the multimodal personalized pre-trip planning and dynamic route guidance customers (but not the advisory-based traveler information users).

For the advisory-based traveler information, additional variable message signs, kiosks, and highway advisory radio sites are assumed to be put in place under this alternative. Public access internet is still assumed to be provided, but given its characteristics relative to the advanced ATIS services, it is characterized more along the lines of the basic traveler information. Given the improved surveillance capabilities that are assumed in the ITS Rich Alternative, it is more likely that a higher percentage of travelers will believe the information provided to be credible and will respond to it than in the Baseline.

The multimodal personalized pre-trip planning service is assumed to be a new service that combines detailed knowledge of network conditions and planned events such as construction activities with knowledge about transit conditions in order to provide customers with comparative information on the outcomes of using different travel modes and routes for their trip (before they depart). It is assumed to be personalized with traveler preferences on travel modes, normal destinations, etc. The travelers are assumed to be able to choose a mode based on the service, and, if the mode chosen is automobile, then the currently fastest route (at the departure time) is assumed to be provided to them. No real-time updates are provided after they depart (although they can still receive advisory-based information). Ten percent of travelers in the study corridor are assumed to use this service. Although no unique capital requirements are levied, since the customers use equipment bought for other purposes to receive the service, a monthly fee of $10 is assumed to handle the total cost transfer requirements to the private sector information service provider.

Dynamic route guidance is another new service assumed under the ITS Rich Alternative. In addition to receiving regular route updates based on current traffic conditions, the vehicles are assumed to be capable of reporting their travel times on certain links as they traverse the network (providing probe reports). Ten percent of SOV and HOV travelers in the study corridor are assumed to use this service. The capital requirements include in-vehicle equipment costs of vehicle location system, map database, and communications equipment, processing hardware and software, and a graphical user interface/display and/or speaker system. A monthly fee of $10 is assumed to handle the total cost transfer requirements for the real-time updating to the private sector information service provider. Another monthly fee of $5/month is assumed to handle the marginal charges for data communications.

The ATIS services discussed above highlight some challenges mentioned in Section 3 regarding incorporating ITS into corridor-level planning studies. These include making assumptions about the private consumer marketplace and associated resource requirements, public-private partnerships, and the decision-making context. These issues will be discussed further in the last section on analysis and implications of the case study (Section 10).

6.3.3 SOV Capacity Expansion Alternative

Currently, SR 99 parallels I-5 and is both an undivided arterial and a limited access expressway. From SR 599 to SR 509 in the south, SR 99 is a limited access freeway. It then becomes an arterial to just before Spokane Street where it then reverts back to a limited access freeway as it passes through downtown Seattle. North of downtown to Winona Avenue N (just past the Woodland Park Zoo), it operates as a divided arterial expressway. Other than at interchanges through this section, access is by right turn on and off only. North of Winona, it becomes an arterial once again and continues as such until it connects with I-5 near Mukilteo.

Two potential options to upgrading SR 99 were initially studied:

(a) *Arterial expressway option*: the portion of SR 99 north of Winona Avenue N would be improved to operate as an arterial expressway

(b) *Elevated expressway option*: a viaduct structure providing two lanes in each direction would be built above the existing SR 99 roadway from Everett Mall Way in south Snohomish County to just south of Winona Avenue N.

Option (a) was selected and further developed as the most promising and realistic of the two alternatives. Both options would have environmental issues (particularly related to ROW and aesthetics) to overcome, but the arterial expressway option is generalizable in terms of alternative types and methodology development. It should be emphasized that this option is not supported locally, and while generically feasible at the planning level may have detailed engineering issues to overcome at specific locations (again, detailed engineering was not carried out as part of this analysis method case study).

Figure 6-5 depicts the alternative configuration and limits. Under this alternative, the portion of SR 99 north of Winona Avenue N would be improved to operate as an arterial expressway, similar to how it currently operates between downtown and Winona Avenue. This would involve limiting access to and from SR 99 by placing median barriers to eliminate left turns onto and off of SR 99. This limited access highway could extend to the King/Snohomish County Line or as far north as Everett Mall Way in south Snohomish County if traffic volumes warrant it. Interchanges would be built at ten critical intersections, and grade separated crossings at nine others (see Figure 6-5 for locations). Most of the interchanges are assumed to be tight, full diamond interchanges with bi-directional ramps. Due to its characteristics, a pair of half-diamond interchanges is assumed for N 80th Street/Green Lake Drive/N 85th Street. Another component of the SOV Capacity Expansion Alternative is that SR 525 (in the northern portion of the study corridor) would be widened from 2 to 4 total lanes between SR 99 and I-5. Several King County Metro and Community Transit routes are affected by this alternative.

6.3.4 SOV Capacity Expansion Plus ITS Alternative

This alternative combines the traditional improvements of the SOV Capacity Expansion Alternative with the ITS strategies in the ITS Rich Alternative. The traditional improvements remain exactly as specified in Section 6.3.3. The only changes to the ITS strategies from the ITS Rich specification are attributed to the characteristics of the SOV Capacity Expansion alternative. These changes are mainly oriented to the SR 99 Expressway:

- The signal coordination system around the upgraded expressway needs to be changed. SR 99 mainline won't have signals within the study area, because of the introduction of the expressway with interchanges and grade separated crossings. However, the intersection of the ramps and the cross streets for the new interchanges will be part of the overall coordinated/adaptive signal system.

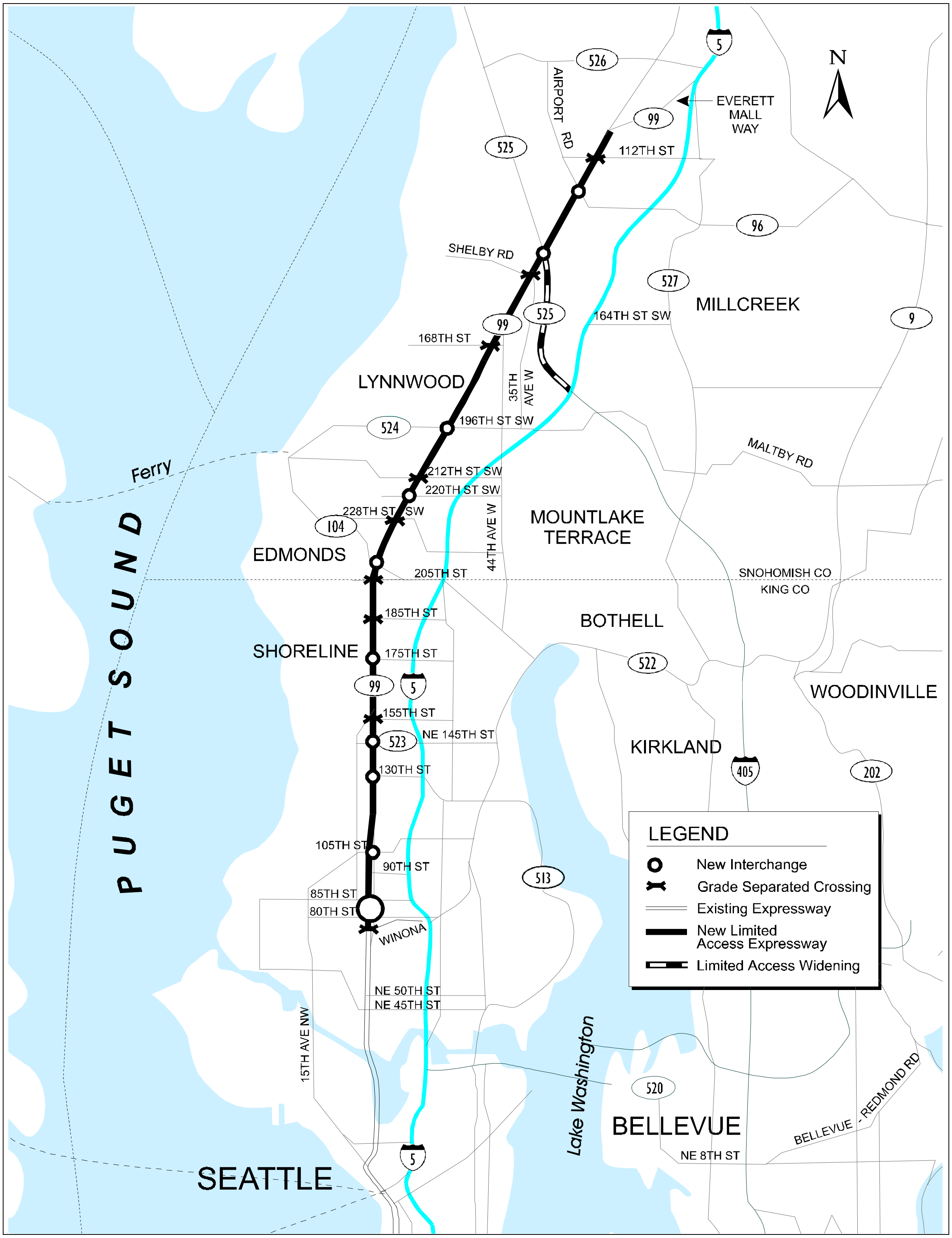


Figure 6-5. SOV Capacity Expansion Alternative

- The SR 99 expressway is included as a part of the TMS (surveillance) expansion plan in the corridor, because of its character as a limited access, higher volume expressway. This segment, which is an addition to the ITS Rich expansion plan, would extend along the length of the upgraded expressway and also south of Winona down across the bridge over the ship channel.

- A ramp meter installation is proposed for the ramp from SR 99 to SR 525 SB, in order to provide the opportunity to meter the flows being fed into I-405 and I-5.

Figure 6-6 shows these changes in context with the SOV Capacity Expansion components.

6.3.5 HOV/Busway Alternative

Figure 6-7 depicts the roadway improvements and other physical enhancements of the HOV/Busway Alternative. Under this alternative, the I-5 freeway would have continuous, barrier-separated, high occupancy vehicle (HOV) lanes from downtown Seattle to SR 526 in South Everett. To achieve this, it would require adding a movable barrier-separated southbound contraflow HOV lane on the express lanes during the PM peak from Ravenna Boulevard to Stewart Street as proposed in the Puget Sound HOV Pre-Design Studies. This would require adding a new lane through the University District and lane conversion between the north end of the Ship Canal Bridge and Stewart Street. A ramp at NE 42nd Street would provide bus access to the southbound contraflow lane.

The HOV lanes in the I-5/North Corridor would become an "HOV Expressway" by adding new direct access ramps to/from park-and-ride lots and bus flyer stops and barrier separating the HOV lanes from the general purpose lanes. HOV access would be provided to I-5 near the International District Station in downtown Seattle. A new freeway to freeway HOV connection would be provided by constructing a reversible HOV ramp between SR 520 and the I-5 express lanes. At the I-5 express lanes and NE 50th Street, a new HOV ramp would provide direct access to and from the North while at I-5/NE 145th, direct access ramps would be added to and from the south.

In Snohomish County, direct access/freeway-to-freeway HOV improvements would include:

- Direct access to/from the south and the north at the Lynnwood Park and Ride
- HOV-only interchange to/from south at 164th/SR 525
- Direct access to/from south at I-5/SW 128th Street
- Direct access to/from south at 164th/Ashway Park & Ride Lot/I-5
- SR 526 to I-5 HOV connection to and from the south
- I-5/I-405/SR 525 HOV connections

Other physical improvements which comprise the Busway/HOV Alternative are those included in the long-range plan for the region, including completion of HOV lanes on SR 99

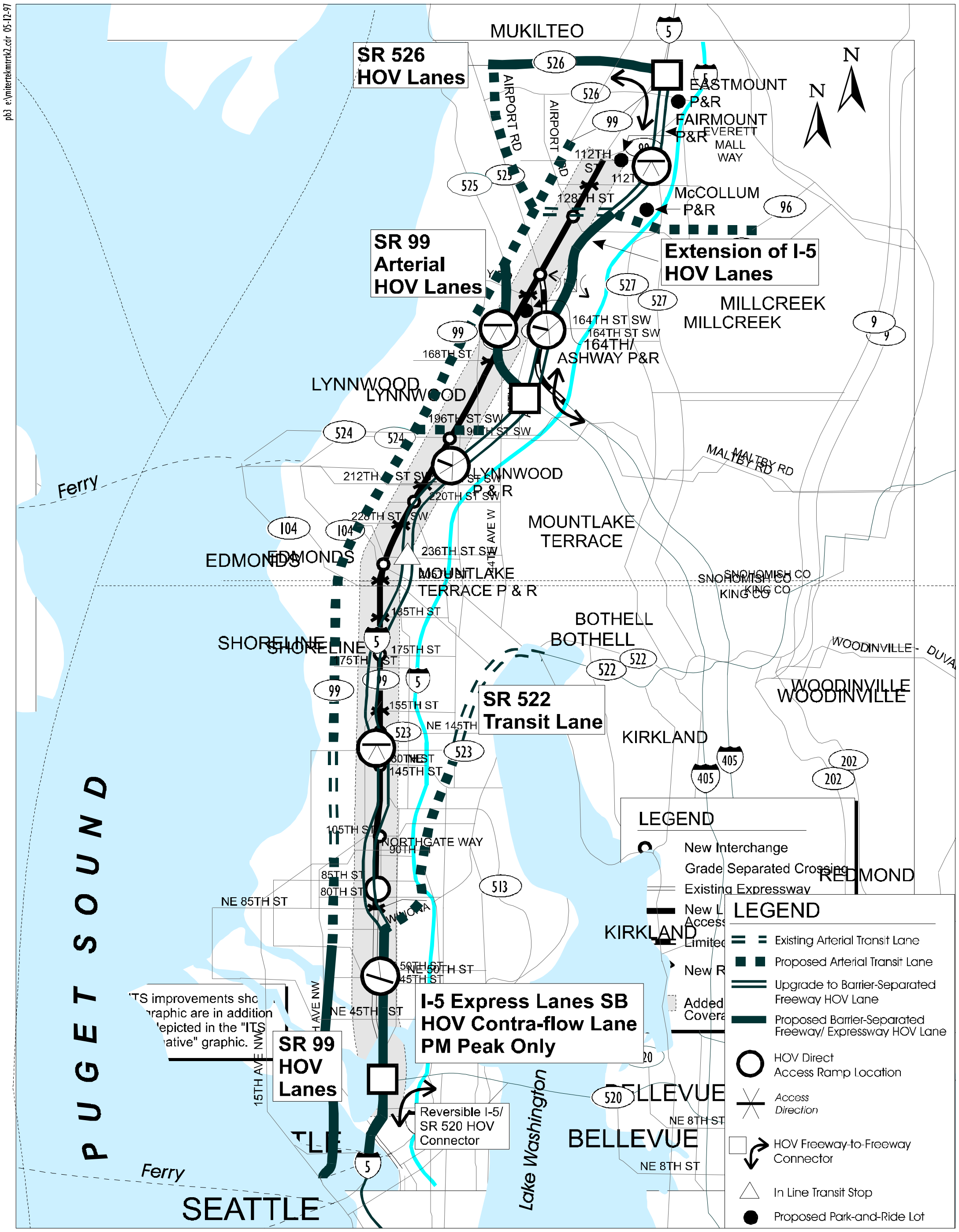


Figure 6-6. SOV Capacity Expansion Plus ITS Alternative

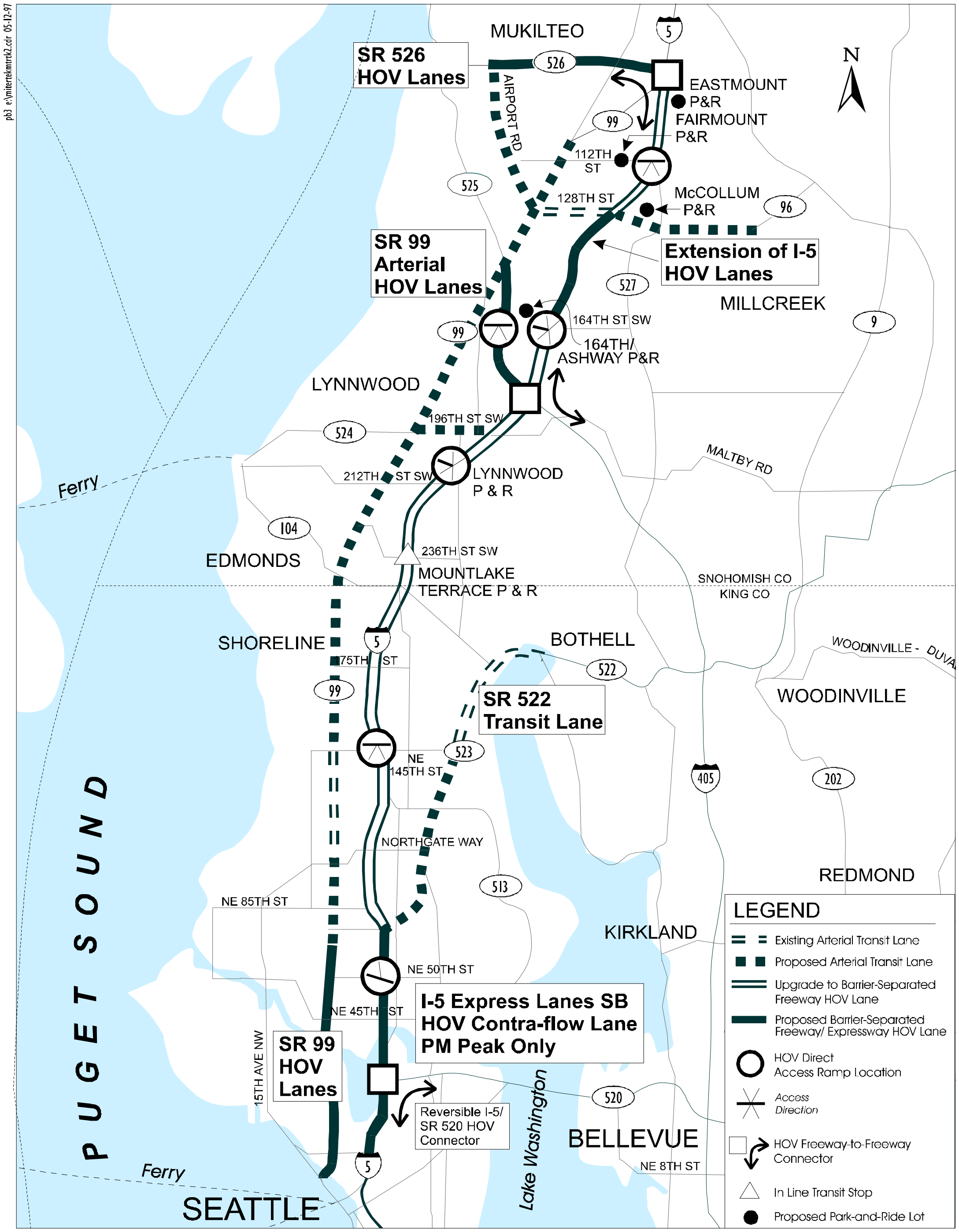


Figure 6-7. HOV/Busway Alternative: Roadway Improvements/HOV Direct Access

Other physical improvements which comprise the Busway/HOV Alternative are those included in the long-range plan for the region, including completion of HOV lanes on SR 99 and SR 526 and a transit lane on SR 522.

Figure 6-8 depicts the transit service improvements of the HOV/Busway Alternative. In keeping with the proposed RTA plan (Regional Transit Authority, 1996), nine new regional express bus routes would be added to provide access to Seattle and North King County centers. The routes would provide fast and frequent service (most would have 15 minute peak and 30 minute off-peak headways) throughout the day, connecting communities such as Lake Forest Park, Northgate, Shoreline and West Seattle to the region. The Everett to Seattle via I-5 route is considered to run with 10 minute peak and 20 minute off-peak headway. The express bus routes are bi-directional (i.e., serve both directions with layovers) and travel non-stop along expressway and major arterial stretches (the stops are indicated on Figure 6-8). Four new regional express bus routes would connect Snohomish County to such destinations such as Everett Community College, Alderwood Mall, Everett mall, Southeast Everett/Boeing, the Technology Corridor (Canyon Park), the University of Washington and Microsoft. The new regional express routes include:

- Everett to Seattle via I-5
- Everett to Seattle via SR 99
- SW Everett to Bellevue via SR 527
- Lynnwood to Bellevue via I-405
- Woodinville to Northgate via SR 522
- Northgate to Issaquah via I-5, SR 520, and I-90
- University District to Redmond via SR 520
- Seattle to Bellevue via I-90

6.3.6 HOV/Busway Plus ITS Alternative

This alternative combines the elements of the HOV/Busway Alternative with the elements of the ITS Rich Alternative in order to see their effectiveness when combined. The traditional improvements remain exactly as specified in Section 6.3.5. There are only very minor changes to the configuration of ITS strategies from the ITS Rich specification; these are attributable to the changes introduced by the construction and service characteristics of the HOV/Busway alternative. These changes are discussed below:

- The signal coordination/ramp metering system may need some very minor tailoring (changes in signal locations, operations plan adjustments, etc.) to account for new HOV direct access ramps. Boulevard to Stewart Street as proposed in the Puget Sound HOV Pre-Design Studies. This would require adding a new lane through the University District and lane conversion between the north end of the

Ship Canal Bridge and Stewart Street. A ramp at NE 42nd Street would provide bus access to the southbound contraflow lane.

The HOV lanes in the I-5/North Corridor would become an "HOV Expressway" by adding new direct access ramps to/from park-and-ride lots and bus flyer stops and barrier separating the HOV lanes from the general purpose lanes. HOV access would be provided to I-5 near the International District Station in downtown Seattle. A new freeway to freeway HOV connection would be provided by constructing a reversible HOV ramp between SR 520 and the I-5 express lanes. At the I-5 express lanes and NE 50th Street, a new HOV ramp would provide direct access to and from the North while at I-5/NE 145th, direct access ramps would be added to and from the south.

In Snohomish County, direct access/freeway-to-freeway HOV improvements would include:

- Direct access to/from the south and the north at the Lynnwood Park and Ride
- HOV-only interchange to/from south at 164th/SR 525
- Direct access to/from south at I-5/SW 128th Street
- Direct access to/from south at 164th/Ashway Park & Ride Lot/I-5
- SR 526 to I-5 HOV connection to and from the south
- I-5/I-405/SR 525 HOV connections

Other physical improvements which comprise the Busway/HOV Alternative are those included in the long-range plan for the region, including completion of HOV lanes on SR 99 and SR 526 and a transit lane on SR 522.

Figure 6-8 depicts the transit service improvements of the HOV/Busway Alternative. In keeping with the proposed RTA plan (Regional Transit Authority, 1996), nine new regional express bus routes would be added to provide access to Seattle and North King County centers. The routes would provide fast and frequent service (most would have 15 minute peak and 30 minute off-peak headways) throughout the day, connecting communities such as Lake Forest Park, Northgate, Shoreline and West Seattle to the region. The Everett to Seattle via I-5 route is considered to run with 10 minute peak and 20 minute off-peak headway. The express bus routes are bi-directional (i.e., serve both directions with layovers) and travel non-stop along expressway and major arterial stretches (the stops are indicated on Figure 6-8). Four new regional express bus routes would connect Snohomish County to such destinations such as Everett Community College, Alderwood Mall, Everett mall, Southeast Everett/Boeing, the Technology Corridor (Canyon Park), the University of Washington and Microsoft. The new regional express routes include:

- The introduction of arterial transit lanes will have an impact on the operation of the Transit Priority system along SR 99 and SR 522 and 196th Street, SW. Because transit vehicles now have their own lane, queue spill-back is likely to be less of a problem. The overall ability of the Transit Priority system to facilitate bus movement (according o the operations policies established) will be enhanced along these streets.

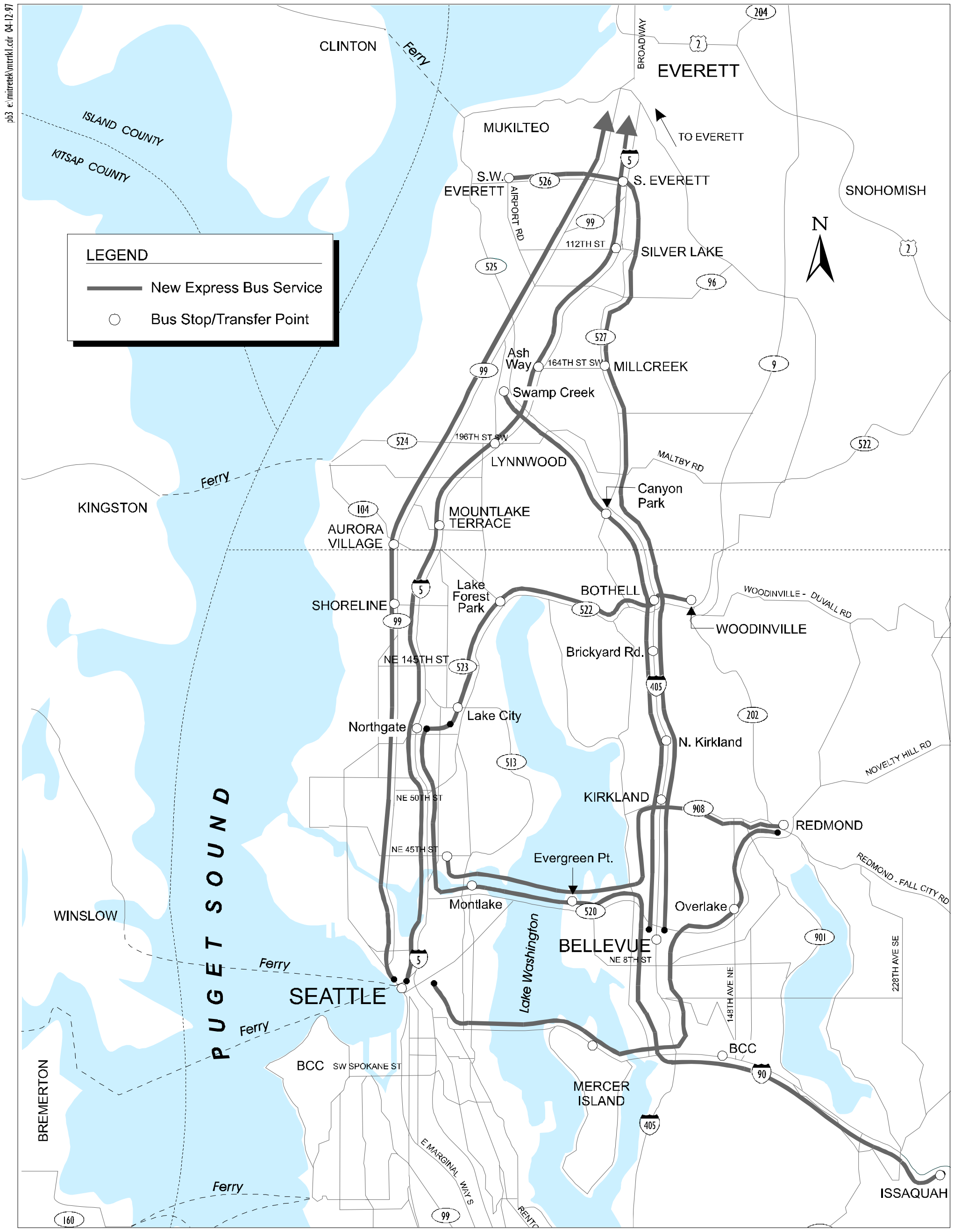


Figure 6-8. HOV/Busway Alternative: Regional Express Bus Service